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[*Continued on page (III) of Cover.*

Johnstone Wright.

PRESIDENT 1939-1940

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VOL. 86.

INAUGURAL ADDRESS

By JOHNSTONE WRIGHT, President.*

(Address issued 26th October, 1939, to members in the United Kingdom and Eire.)

(1) GENERAL

In his Presidential Address last year,† Dr. Fleming referred to the international crisis just then passed. All hopes of peace have since been shattered, and the opening of the 1939–1940 Session finds Great Britain engaged in a war which must profoundly affect the future course of world history. It is in keeping with our high traditions that even in such momentous circumstances the work of The Institution should carry on unbroken.

At no time could a greater honour be conferred on a member of The Institution than to be elected President; but even in times of peace it would be difficult to maintain the exacting standard set by my predecessors, and I cannot but be very conscious of the exceptional responsibilities entailed by the circumstances in which I take office. None the less, with your co-operation and help I will do my best to continue the great traditions of this high position.

Even before the outbreak of war The Institution was playing its part by marshalling the technical knowledge and experience of its members, to ensure the best use in emergency of what is undoubtedly a great national asset. National defence has already presented many problems to electrical engineers, particularly to those in the electricity supply industry whose duty it is to ensure continuity of supplies, and in present conditions protection against air raids has unfortunately become a new basic factor in design. The war will doubtless bring us many further problems, but the high standards of professional conduct and attainment found in the ranks of The Institution are the best possible assurance that all such problems will be solved successfully, and that The Institution will take in the national struggle a place worthy of our great heritage.

The work of The Institution during the war of 1914–1918 is recorded in Mr. Appleyard's "History," which has just been published and which tells the entrancing story of The Institution from its establishment in 1871 until the present time. It should be studied by all members, not merely as a record of the achievements of illustrious engineers of the past, but also as an example which present and future generations should strive to emulate.

Turning to the affairs of The Institution itself, it is fitting to refer first of all to the retirement of Mr. P. F. Rowell, our Secretary, who has served The Institution for the past 38 years. To most members Mr. Rowell and The Institution have become synonymous, and his unique and splendid contribution to its development will be of permanent value. I feel I am voicing the sentiments of all our members in wishing that the war may not unduly affect Mr. Rowell in his well-earned retirement.

My next duty is to welcome Mr. W. K. Brasher, our new Secretary, on whom falls the difficult and important task of succeeding Mr. Rowell at such a critical stage in our history. Mr. Brasher is not a stranger to The Institution; he is a Member who has resided abroad for some years and has great administrative experience, in addition to high technical qualifications. I wish him every success in his new sphere.

It is customary that the Address of the President should be coloured by his own experience in the years preceding his election. No apologies are needed, therefore, for my having chosen the phase of electrical engineering which has absorbed my attention during the past 12 years. Indeed, the choice of the construction and operation of the Grid as the subject for this Address is particularly appropriate, not merely because it touches the interest of all sections of The Institution, but also by reason of the significant coincidence that your incoming President on the outbreak of the war of 1914–1918 was the late Sir John Snell, to whose vision, enthusiasm and advocacy the Grid is so largely due. The deficiencies in national electrical organization revealed by that war resulted in the establishment of the Grid, and it is surely not too much to claim that the Grid has a vital national role in the present struggle.

In his Address in 1927, Sir Archibald Page dealt very fully with the history of electricity supply in Great Britain prior to the passing of the Act which established the Central Electricity Board. At that time the construction of the Grid had just begun. In the interim,

* Central Electricity Board. † *Journal I.E.E.*, 1939, **84**, p. 1.

several papers have been presented to The Institution dealing with the various aspects of Grid design and construction novel to this country. The novelty of construction has now passed away, the Act is familiar to members of the supply side of the industry, and, in addressing The Institution generally, matters must be mentioned which to some may appear hackneyed. I feel, however, it will be useful to The Institution at this critical juncture to have an account of the Grid as an established entity, and to summarize some of the experience gained and progress made from an engineering and national standpoint since the passing of the 1926 Act.

(2) GRID CONSTRUCTION

The projected layout of the Grid was given in Sir Archibald Page's 1927 Presidential Address.* While into operation on a large scale abroad and on a relatively modest scale in this country, but the Grid constitutes the first application of these principles to the electricity supply system of an entire country.

The financial results up to the outbreak of war are even better than those envisaged in the programme of development. It is only necessary here to refer to the effect on the capital expenditure of the supply industry, shown in Fig. 2, which reveals that, on the grounds of conservation of capital resources alone, the Grid has already made a substantial net contribution to economy. It also shows, incidentally, that the Grid construction and standardization of frequency, planned in the comparative prosperity of 1924–1929 and carried out largely in the period of acute depression which followed, resulted in a substantial increase above the

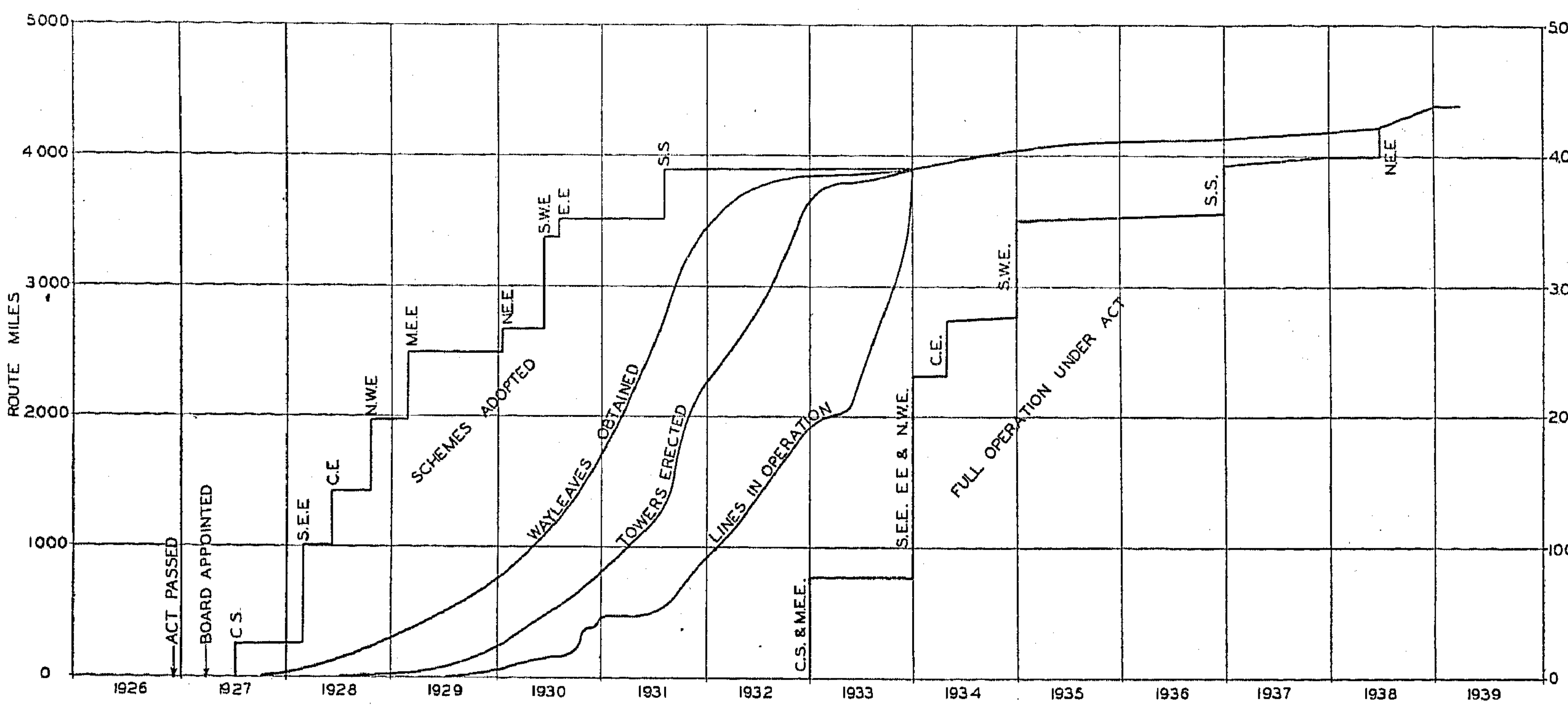

Fig. 1.—Progress of Grid schemes.

that original scheme was generally adhered to when detailed plans came into practice, it is undesirable, for obvious reasons, to publish any detailed comparative maps at the present time. Table 1 shows the characteristics of the scheme areas and the general particulars of the Grid at the 31st December, 1938, and Fig. 1 gives a comprehensive summary of the progress on actual Grid construction from the passing of the 1926 Act to full operation. The only part of the country now not covered by a scheme in full operation is North Scotland, for which no scheme is at present contemplated.

This country has comparatively little need to transmit power over long distances, as sources of energy are adjacent to each other and to load centres. The general underlying functions of the interconnecting system provided by the Grid are:—

(a) To reduce the proportion of reserve plant required in individual stations, and

(b) To secure the highest practicable load factor for the most efficient plant on the system.

Interconnection of a similar kind had already been put

* *Journal I.E.E.*, 1928, **66**, p. 1.

normal capital expenditure of the industry at a time when such expenditure was most needed. The policy has had the less tangible, but possibly equally valuable, effect of affording our manufacturers extensive and intensive experience in design and construction of large high-voltage power plant, thus putting them in a position of equality with their competitors abroad.

(3) STANDARDIZATION OF FREQUENCY

In 1924–1925 seventeen different frequencies were employed in the alternating-current systems of Great Britain, and no less than 80 undertakings were distributing alternating current at frequencies other than 50 cycles per sec. The existence of large systems operating on a variety of frequencies was a grave handicap to commercial development and seriously limited the benefits to be obtained from a comprehensive scheme of interconnection. The principal areas which had to be changed to the 50-cycle basis chosen as standard are shown in Fig. 3.

The experts advising the Weir Committee considered that the standardization desirable for grid purposes, if undertaken in 1924, would cost £10½ millions. When the

Table 1

POSITION OF GRID SCHEMES AT 31ST DECEMBER, 1938

Item	North Scotland	Central and South Scotland	North-East England	North-West England and North Wales	Mid-East England	Central England	South-East and East England	South-West England and South Wales	Totals
Area (square miles)	20 509	9.288	5 049	9 082	7 546	7 311	12 266	17 090	88 141
Population, 1937 (from Registrar-General's estimates)	808 829	4 167 781	2 664 042	7 133 295	4 963 341	5·830 338	14 135 106	6 304 878	46 007 610
Population per sq. mile	39·44	448·73	527·64	785·43	657·74	797·48	1 152·38	368·92	521·98
Electricity generated during 1938 by authorized undertakers (millions of units)	607·321	1 838·086	1 568·568	3 880·814	2 750·106	3 624·851	7 927·599	2 174·723	24 372·068
Selected stations:									
Number	—	16	6	28	17	20	35	15	137
Generating plant installed (kW)	—	752 615	439 150	1 406 150	865 175	1 371 850	2 824 775	604 445	8 264 160
Lengths of lines and cables under control (route miles):—									
132 kV	—	475·31	91·44	314·80	327·77	455·29	699·00	630·10	2 993·71
Lower voltage	—	154·78	97·02	284·52	202·91	53·42	462·53	129·29	1 384·47
Totals	—	630·09	188·46	599·32	530·68	508·71	1 161·53	759·39	4 378·18
Switching and transforming stations: Number:									
132 kV	—	22	5	23	13	18	35	23	139
Lower voltage	—	26	11	33	16	4	70	14	174
Totals	—	48	16	56	29	22	105	37	313
Installed capacity of transformers (kVA):									
132 kV	—	902 000	240 450	1 170 000	700 000	1 320 000	2 282 500	919 200	7 534 150
Lower voltage	—	56 900	171 000	497 000	342 200	20 000	1 681 250	140 000	2 908 350
Totals	—	958 900	411 450	1 667 000	1 042 200	1 340 000	3 963 750	1 059 200	10 442 500
Length of communication channels (radial miles)	—	521	200	781	563	528	1 547	1 018	5 158

Electricity Commissioners prepared the detailed schemes, the estimated figure had risen to about £14½ millions, and by the time the work was actually put in hand, on dates spread over 1928 to 1930, the estimated gross cost was some £18½ millions. The actual expenditure up to the end of 1938, when the work was virtually complete, was £17·3 millions, some part of which is recoverable as antedated expenditure subsequently needed to meet normal development. The magnitude of this increase in cost with efflux of time clearly indicates that the cost of standardization would have become prohibitive if further delayed. Indeed, but for the retarded expansion of industry during the trade depression from 1930 to 1934, the amount of apparatus to be dealt with would have been greater; had the decision to standardize been delayed until the present time, the cost would have been well over £30 millions. The industry has been relieved of some part of the burden of the increased cost of standardization, since the Central Electricity Board was instrumental in securing Government Unemployment Assistance Grants, which have already relieved the industry of annual charges aggregating up to the end of 1938 £1·74 millions.

The benefits arising from standardization are difficult to assess with any precision. The savings attributable to the Grid system, which are already substantial, could not have been on the same scale had standardization not been undertaken, and, in addition, economies in the costs of production of transformers, motors, convertors, meters and instruments, are not inconsiderable, and must give rise to benefits to the undertakers, consumers and manufacturers. It is at least questionable, for instance, whether any considerable market for electrical clocks could have been developed if non-standard frequencies had persisted; while of much greater importance is the fact that national defence requirements have undoubtedly been simplified by the existence of a national standard-frequency basis.

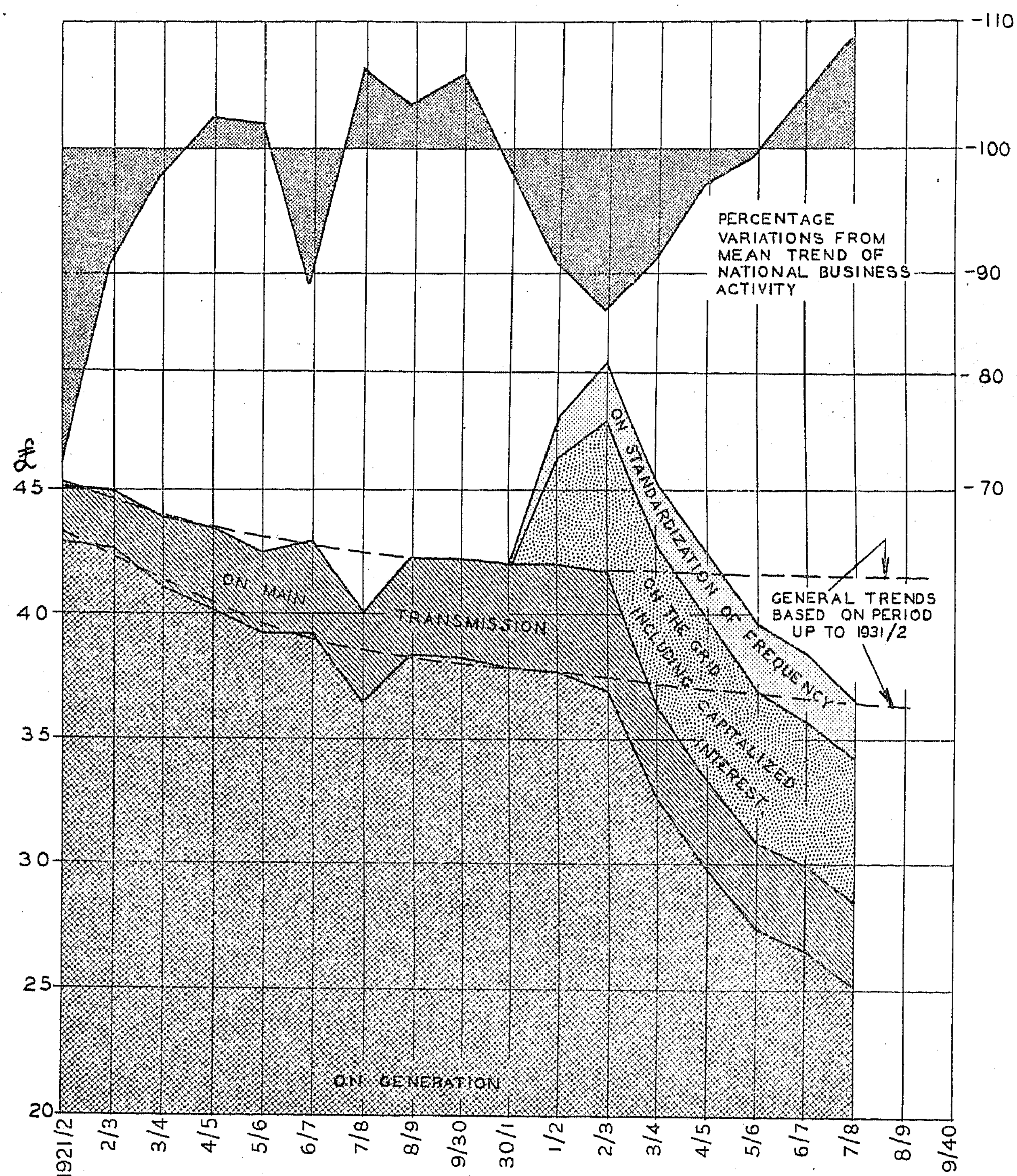

Fig. 2.—Capital expenditure by electricity supply industry in Great Britain (per kW of aggregate maximum demand sent out to local distribution systems).

Since the benefits of standardization are so widely dispersed, it is appropriate that the costs should be spread over the whole of the supply industry. It will be seen from Fig. 4 that the maximum burden actually placed on the supply industry in any year has been 0·88 % of the revenue from electricity sales, and that the peak incidence has now been passed.

The magnitude of the work involved can be gauged from Table 2. It is very much to the credit of the electricity supply industry that the undertakers concerned have changed over to standard frequency more than 1 900 000 h.p. of motors on consumers' premises without dislocation of industrial production, and over 900 000 kW of turbo-alternators without unduly encroaching upon reserve generating-plant capacity.

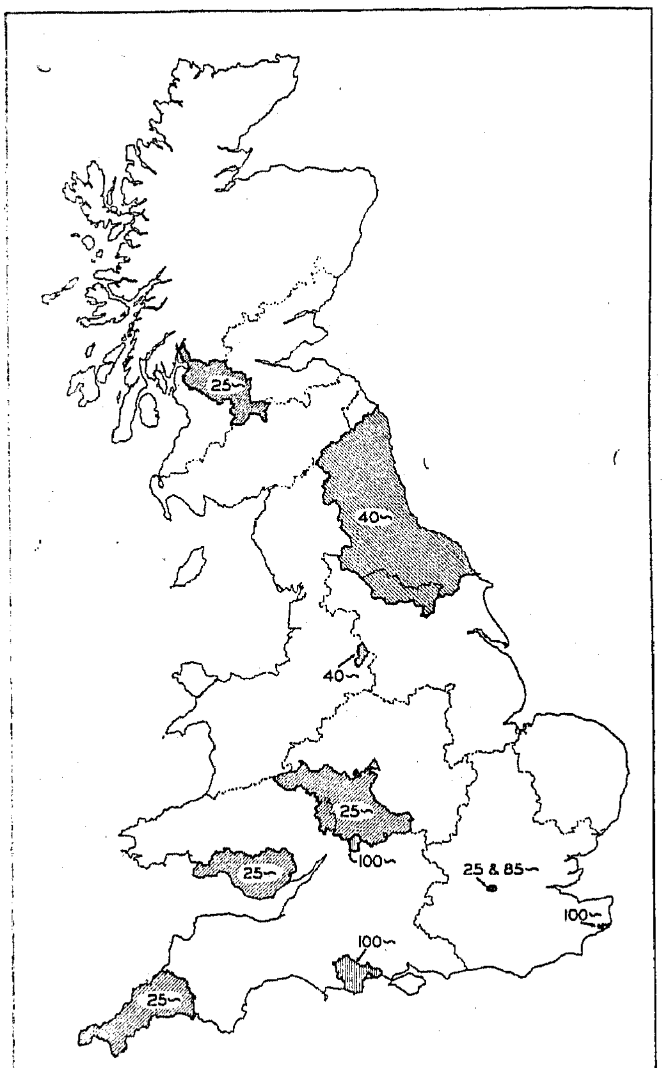

Fig. 3.—Areas changed from non-standard alternating-current frequency.

(4) OPERATION AND MAINTENANCE OF GRID EQUIPMENT

(a) General

The technical performance of the Grid as a whole undoubtedly reflects great credit on British engineering, which has been responsible for practically every item of equipment. The purpose of this Address, however, is not to extol this performance, but rather to review experience frankly, pointing out any difficulties encountered and overcome. A complex electrical system, erected at a cost to date of over £30 millions, can hardly be expected to be entirely free from faults. No fault is allowed to pass without the closest examination, and it can be claimed that in relation to the size of the system the number of faults is small. The overhead lines have proved their reliability in conditions of severity even in excess of those envisaged in the official Regulations, and it is noteworthy that no 132-kV tower has been destroyed or even seriously damaged by natural agencies. The numerous high towers for river crossings, canal overbuilds and multiple-circuit towers, are individual achievements in structural engineering which have proved entirely satisfactory.

(b) Steel-Cored Aluminium Conductors

The conductors have proved suitable for all classes of line. There have been jointing troubles, necessitating new types of joint, and vibration experience has led to the general precautionary fitting of anti-vibration dampers. In certain small areas, corrosion led the Board to use suitable protective coatings, but on over 99 % of the total length of lines aluminium deterioration is less than 1 % per annum for the outer layer and still less for the inner, while only a few insignificant instances of deterioration of the galvanized steel core have as yet been encountered.

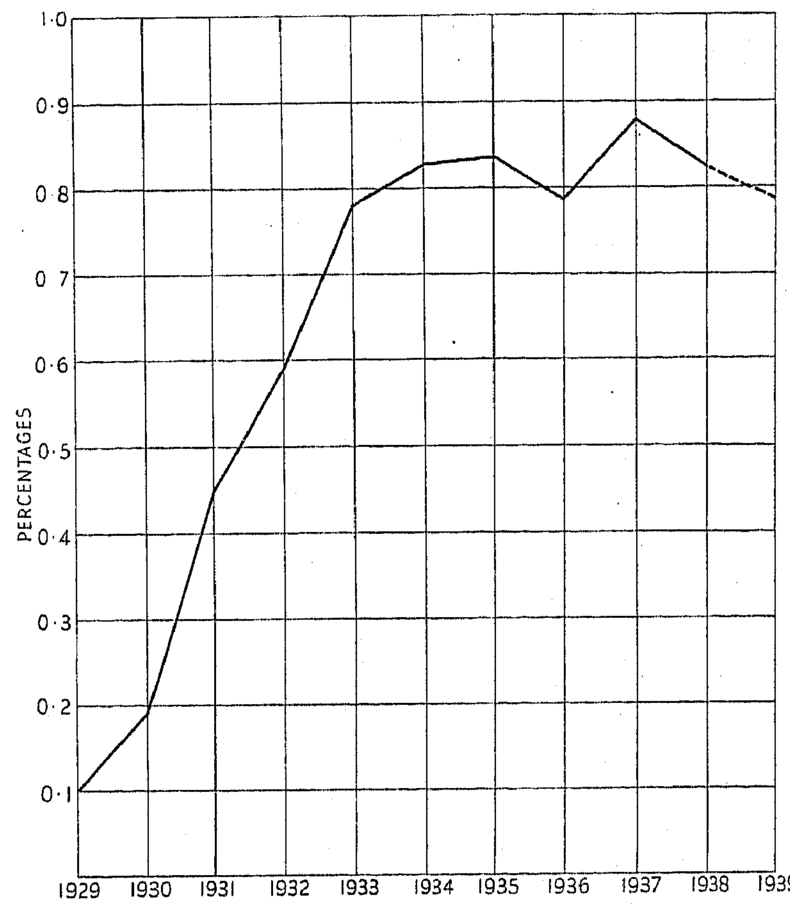

Fig. 4.—Levies made by Electricity Commissioners to meet charges arising from standardization of frequency.

NOTE.—Percentage of revenue in year of account in which levies were payable from sales of electricity, excluding bulk intersales.

(c) Insulation

In many areas in Great Britain high-voltage insulation suffers exceptionally from industrial pollution and fog prevalence, and although the standard line insulators proved eminently satisfactory on about 90 % of the system, for the more vulnerable sections of line special

insulators had to be developed. Fig. 5 shows that this step has brought the problem of flashovers due to industrial dirt, fog and frost, within manageable limits.

Table 2

WORK INVOLVED IN STANDARDIZATION OF FREQUENCY.

Scheme area	Apparatus changed over						Approximate number of consumers affected
	Turbo-alternators		Convertors		Motors		
	No.	Capacity	No.	Capacity	No.	Capacity	
		kW		kW		h.p.	
Central Scotland	29	338 275	308	156 643	31 232	418 996	16 136
Central England	25	209 120	230	150 826	19 067	300 693	93 675
North-East England	64	249 481	137	63 468	41 898	992 850	200 000
North-West England	6	26 670	9	3 140	3 323	37 533	1 104
South-West England	36	106 499	22	8 492	6 669	151 243	82 000
Total	160	930 045	706	382 569	102 189	1 901 315	392 915

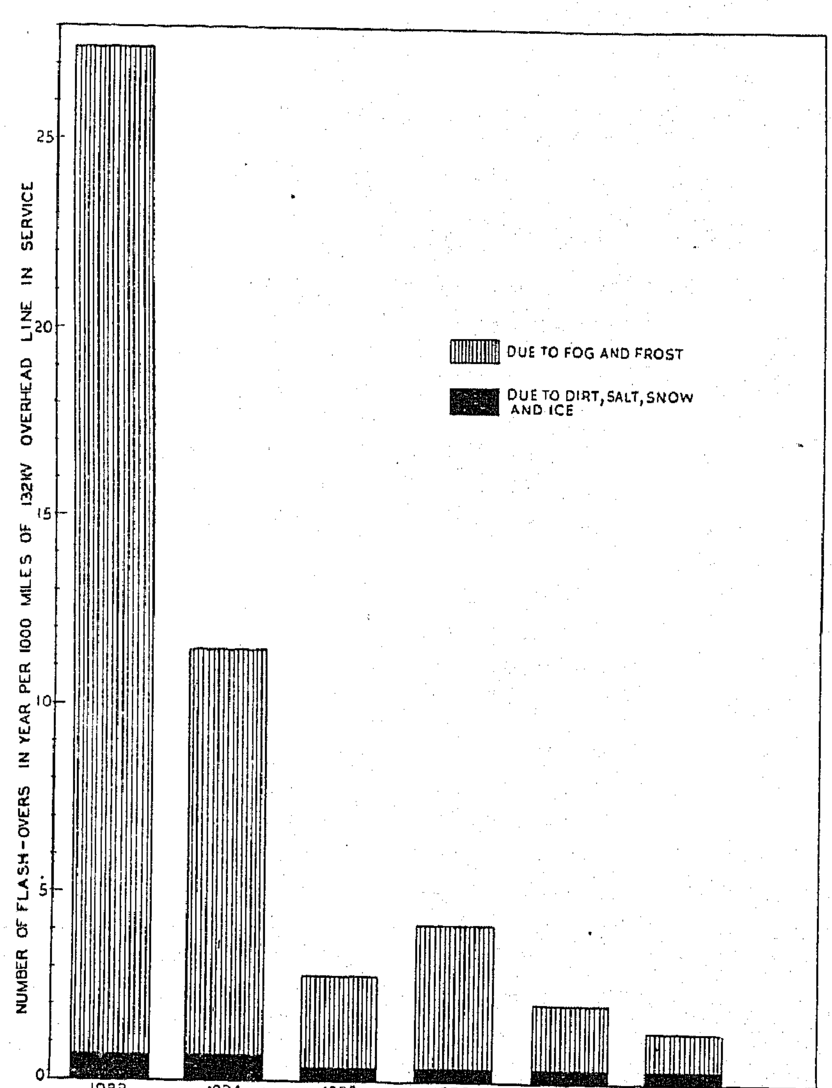

Fig. 5.—Insulator flashovers on 132-kV Grid lines (attributable to all causes other than lightning).

Lightning remains the most frequent cause of faults on overhead equipment, being responsible during the last six years for an annual average per 1 000 miles in service of about nine flashovers on 132-kV lines and 34 on lower-voltage lines. Fortunately, the effects on reliability of supply are not great and damage to transformer insulation, involving lengthy repairs, has been too infrequent to justify the fitting of protective devices except in areas specially prone to lightning.

Bushings for transformers, circuit-breakers, metalclad switchgear and the like, have been remarkably free from trouble. Condenser bushing insulators have shown three general types of weakness—ingress of moisture, surface tracking and puncturing due to internal voids. The remedial improvements, though sufficiently obvious in general terms, require technical skill of a high order, and I record with appreciation that all manufacturers involved have loyally co-operated in the work of rectification.

High specific insulation stress necessitates appropriate testing methods, involving the measurement and examination of the variation of dielectric losses and currents with applied voltages and temperatures. In certain circumstances X-ray examination is also useful. The technique of such measurements and the interpretation of test results are still somewhat obscure to most power engineers, and there is much scope for intensive investigation. I commend the subject to our educational institutions as worthy of their close attention.

In general, the practical results with apparatus incorporating insulating oils and bakelized or other synthetic solid products have been satisfactory, having regard to the vast quantities in service. Anxiety was occasionally caused by failures revealing weaknesses common to large quantities of equipment, but a high standard of electrical and chemical knowledge was fortunately available and such conditions were quickly eliminated.

Twelve years' experience leads to the conclusion that the classes of insulation dealt with will have an adequate economic life. The technique is, however, by no means perfect and there is ample scope for improvement, providing the younger engineers and chemists in this field with new opportunities and new problems to solve for the common good.

(d) Transformers

In 1927, small low-voltage transformers had self-contained on-load ratio-changing gear in only a few exceptional cases. The decision so to fit all Grid transformers has been shown by experience to be wise. Almost every high-voltage transformer in the supply industry is now fitted with such gear as standard practice, with large consequent savings. This change in general policy is sufficient indication of the complete technical success of the Grid equipment, by which British transformer manufacturers made an impressive contribution to electrical engineering, all the more praiseworthy as every unit has to be transportable over British railways with their restricted loading gauge.

While research into surge phenomena in this country may have lagged behind that of other countries in the past, the Board has done much to assist and accelerate British investigation, in collaboration with the British Electrical and Allied Industries Research Association and the National Physical Laboratory, and I consider Great Britain to be well to the fore to-day. It should be possible in the reasonably near future to assess accurately the stresses imposed on transformer windings by lightning, and so to design windings and protective devices that service failures may be eliminated.

Transformer design is advancing in orderly evolution and only one more point need be mentioned here. The Board has already done much to secure quiet transformer operation by insisting in its specifications on the importance of this aspect of design and by applying the latest forms of noise-measuring equipment in transformer testing. It is reasonable to expect that manufacturers will persevere in efforts to provide more and more silent transformers and cooling gear, as it is becoming exceptional for transformer sites to be remote from dwelling houses, and everything possible must be done to ensure that there is no avoidable strain on the inmates of homes adjacent to transforming stations.

(e) Switchgear

The Board's equipment is believed to constitute the largest installation of switchgear operated by one management. In 1927 it was obvious that great changes in circuit-breaking technique were pending, but construction could not be delayed until these matured, and experience indicated no undue hazard in using the then existing types of circuit-breaker, suitably modified to meet the higher voltage conditions.

Short-circuit testing has been in progress for some years and there are now five large testing stations in this country. This testing has resulted in greatly improved safety and increased speed of clearance of faults. Arc-control devices have made possible the renovation of many older types of circuit-breaker to give performance almost comparable with that of the most modern productions. The relations between the short-circuit conditions imposed by test plants and those encountered in supply service are not yet fully understood, but I hope and anticipate that the necessary co-operation between supply authorities and manufacturers, already commenced, will expand until all outstanding questions have been satisfactorily answered.

Switchgear insulation has become almost notorious in recent years as a source of trouble, through the disastrous consequences of what were initially minor and localized failures. Such cases have been few and even the consequential losses, large in themselves, have been small in relation to the magnitude of the supply industry. Nevertheless, it is essential to eliminate such occurrences from our records, and in this connection I would recommend for serious consideration the conclusions of the Investigating Committee appointed by the Electricity Commissioners.*

The development of the oil circuit-breaker to the high-speed, small oil-content stage at which it stands to-day is a fine achievement. The trend of development is aptly illustrated by Fig. 6 (see Plate). Oil-less circuit-breakers, however, have advantages which will probably make them preferable for many applications.

(f) Cables

Owing to the wide extent of built-up areas in this country, extensive sections of high-voltage cables had to be used for Grid connections to selected and other stations, the system to-day comprising $23\frac{1}{2}$ route miles of 132-kV cables and nearly 200 miles at lower voltages. When it is remembered that in 1927 there was practically no experience of 66-kV and 132-kV cables in this or any other country, this work of the British cable makers, of which little has been made public, will be realized as one of the greatest achievements ever accomplished in cable construction and installation.

Every encouragement and opportunity have been given to manufacturers to prove under service conditions any cable having an adequate background of properly controlled works testing. This policy has resulted in healthy technical rivalry in a field where at one time the tendency seemed to be towards monopoly. I will not venture to prophesy which of the rival high-voltage cable systems is likely to predominate; the oil-filled cable has a long start against its more modern rival, the internal gas-pressure cable, but the latter has constructional and technical advantages which force consideration by all potential users of very high-voltage cable.

(g) Protective Equipment

Although used where practicable, the adoption of pilot-wire protection throughout the system was impracticable, since the necessary pilots would have cost some £$3\frac{1}{2}$ millions; in general, reliance had to be placed on the now well-known impedance and reactance types of distance protection. For the year 1938, correct operation of the protective gear as a whole reached a figure of 88 %, and certain of the areas attained the excellent standard of 96 %, which is probably about the maximum attainable with existing equipment and without expenditure disproportionate to the gain to be derived.

Of great promise in overhead-line protection is the development by which power lines themselves are used as pilots for conveying high-frequency tripping or locking impulses. The complicated high-frequency apparatus has not yet been completely adapted to power-engineering

* See Memorandum on "Fire Risks at Generating Stations," published by the Electricity Commissioners, March 1936.

needs, but, taking all factors into consideration, I consider that carrier-current protection will do much to assist power-transmission development.

Before leaving this subject, I wish to interpose a few words regarding the standardization of wiring systems. Much of the time spent by young engineers in their training is expended on obtaining familiarity with numerous unessential variants of what are fundamentally the same schemes. Surely it is to the common interest that schemes should be rationalized so that wiring systems, acceptable to all parties involved, could be utilized by technicians from their college stage onwards. This basic principle applies to all classes of electrical equipment, and I hope some effort will be made to give it general application. Some engineers might regard the loss of picturesque variety as detracting from the interest of our profession, but I am strongly of opinion that variety should be sought in more positive directions than mere permutations and combinations of units which are inherently equivalent, if not identical.

(h) Metering

Special forms of integrating meters, summators, maximum-demand indicators, and printometers, had to be developed to measure and record with the requisite accuracy the various electrical quantities required by the complicated accountancy of the 1926 Act. The British meter manufacturers responded to this need and produced the necessary instruments in what now seems a remarkably short period. The metering equipments have given such excellent service that disputes between the Board and authorized undertakers on the subject of measurements have been negligible. From both personal and technical standpoints it is significant that even in the few controversial cases reference to an outside standardizing authority has not been necessary.

(i) Inductive Co-ordination

There is now extensive experience of the effects of the Grid system on the communication systems of the Post Office, the railway companies, and other important bodies, and I am glad to be able to record no appreciable trouble on the communication systems, interference of either transient or continuous types having been almost non-existent. This satisfactory result has been secured by continuous co-operation between the respective technical staffs. Great Britain came late into the field of high-voltage transmission and so missed much of the controversy between communication and power interests which was a feature of power development abroad. In the United States it had been widely realized that both sides had everything to gain by dispassionate discussion of their technical difficulties. Significantly, their business was conducted under the specific title of "inductive co-ordination" rather than the more usual "inductive interference"—and we have not hesitated to adopt their admirable principles.

The "guiding principles" issued by the International Mixed Committee of Communication and Power Engineers (the "C.M.I.") show the protective steps which communication authorities consider necessary, but they should be regarded as general indications rather than rigid regulations. Some important power schemes have been handicapped by failure to appreciate this, excessive capital expenditure being incurred when a dispassionate examination of the facts by both sides would have revealed inexpensive means of securing the desired degree of safety. This point is surely exemplified by the co-existence in the circumscribed area of this island of the Grid and other large power systems and the vast G.P.O. network of communication circuits.

Radio interference problems have also been dealt with on co-operative lines. In the early stages of Grid operation, complaints from radio users were somewhat numerous, but investigations showed a rather large proportion of these to be unjustifiable, the troubles arising in the radio sets themselves. This was realized by the General Post Office, who soon ensured that the Board were shielded from all except bona-fide complaints. Between 1930 and 1938 only 120 cases of interference had to be considered, and only a small proportion of these necessitated any extensive remedial action. Radio interests should realize, however, that they have their own part to play in making good reception possible, by ensuring adequate radio field strength and technically satisfactory receiving sets. If there is adequate and unbiased co-operation between the interests concerned, it should be readily possible to give the public good and economical service in both power and radio fields. In the past The Institution has been the focal point for discussions of such matters, and I hope this will continue.

(5) SYSTEM OPERATION

(a) System Control

The Board rent from the Post Office, for exclusive use, an extensive network comprising over 5 000 radial miles of communication channels. The service standard provided by the Post Office is a high one, and the provision and maintenance of this system by specialists leave the Board's staff free to concentrate on their own problems of power supply.

The Grid is grouped into seven operational areas, each having a control centre conveniently situated in relation to the Board's District Office. An over-riding National Control has been introduced to co-ordinate the work of these seven Control Centres when inter-area operation is in force. For lengthy periods during last year the whole Grid was run in parallel, without incident, with a maximum load on the interconnected power stations of the order of 6 730 000 kW.

An indication of the rapidity and magnitude of the fluctuations of load dealt with, and of the load effects of exceptional events in our national life, is given in Fig. 7. The left-hand diagram, with all its implications of sleep foregone in thousands of homes, is an amusing sidelight on the sporting instincts of the Briton, while the right-hand curve, recording the sudden wholesale stoppage of industrial and commercial activity in response to a 20-year-old memory, is significant in these days of the tenacity of British sentiment.

The continual extension of the Grid system has called for corresponding extensions of control equipment, and the manufacturers of such equipment, developing on automatic telephone principles, have been most helpful

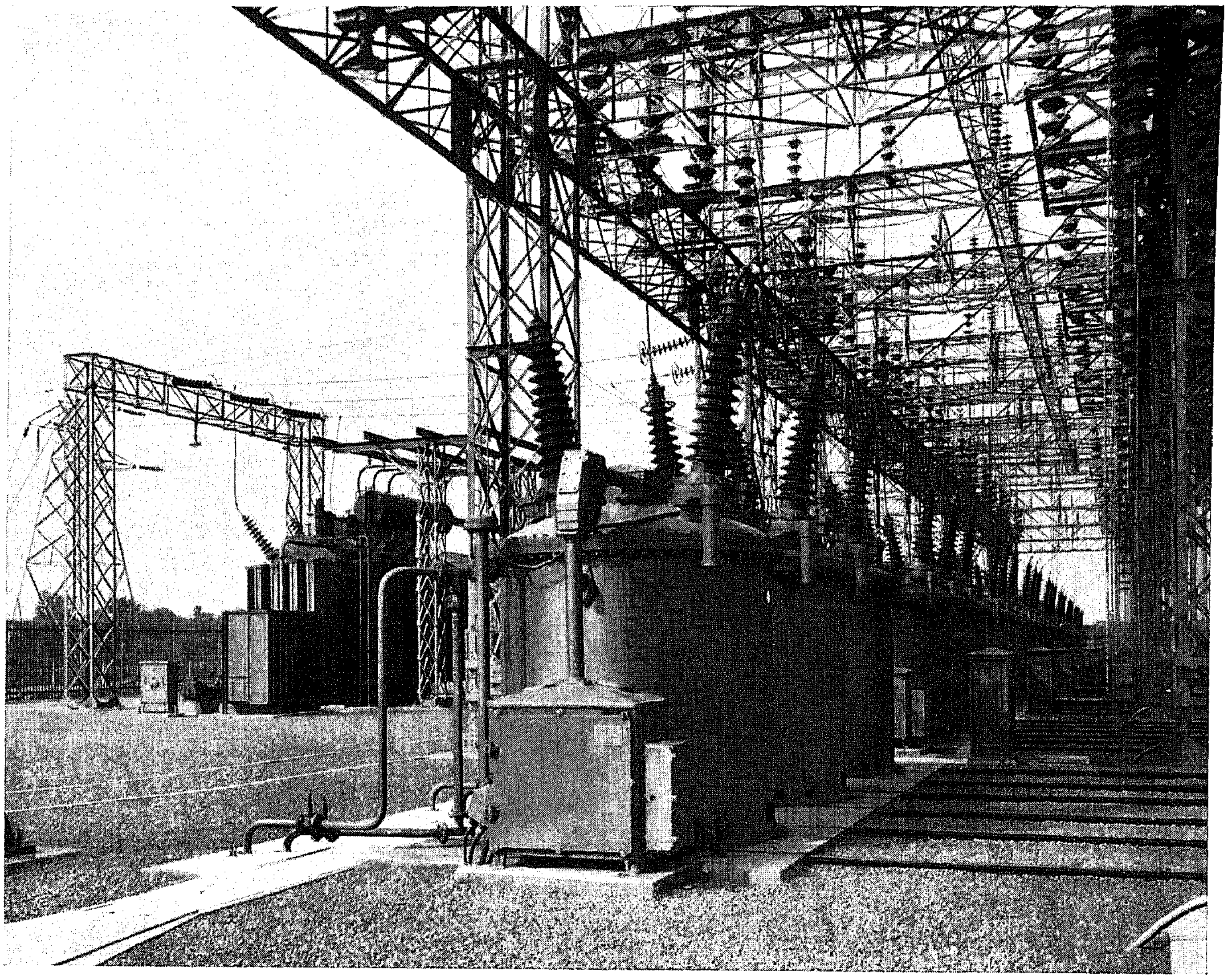

Fig. 6(a).—Bank of standard oil circuit-breakers.

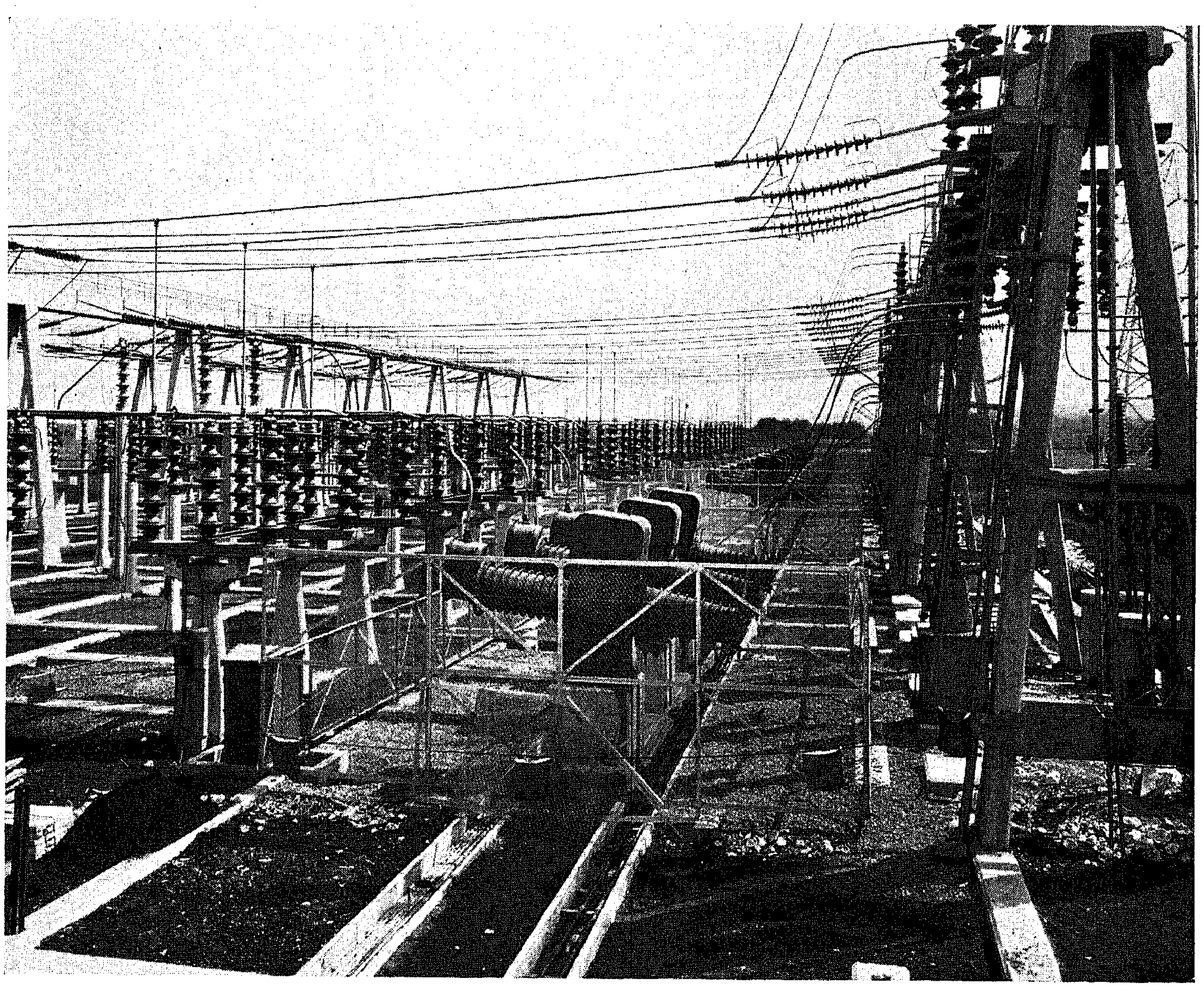

Fig. 6(b).—Bank of high-speed, low oil-content circuit-breakers.

in the solution of the many novel problems which have arisen. As an example in passing, mention may be made of the continuous tele-metering apparatus for use in the Control Centres with the rented Post Office channels, which has been specially valuable in inter-area running. The development of these instruments has been largely in the hands of high-frequency experts, and details of their design and construction will be of much interest to the members of the Wireless Section of The Institution, whom I refer to appropriate specialized descriptions.

(b) Frequency Control

Frequency and time control is carried out from the Control Centres themselves, since with a comparatively large number of stations running in parallel, and with interconnectors of limited capacity, it is necessary to vary simultaneously the outputs of quite a number of stations, in order to obtain the desired alterations of Grid frequency.

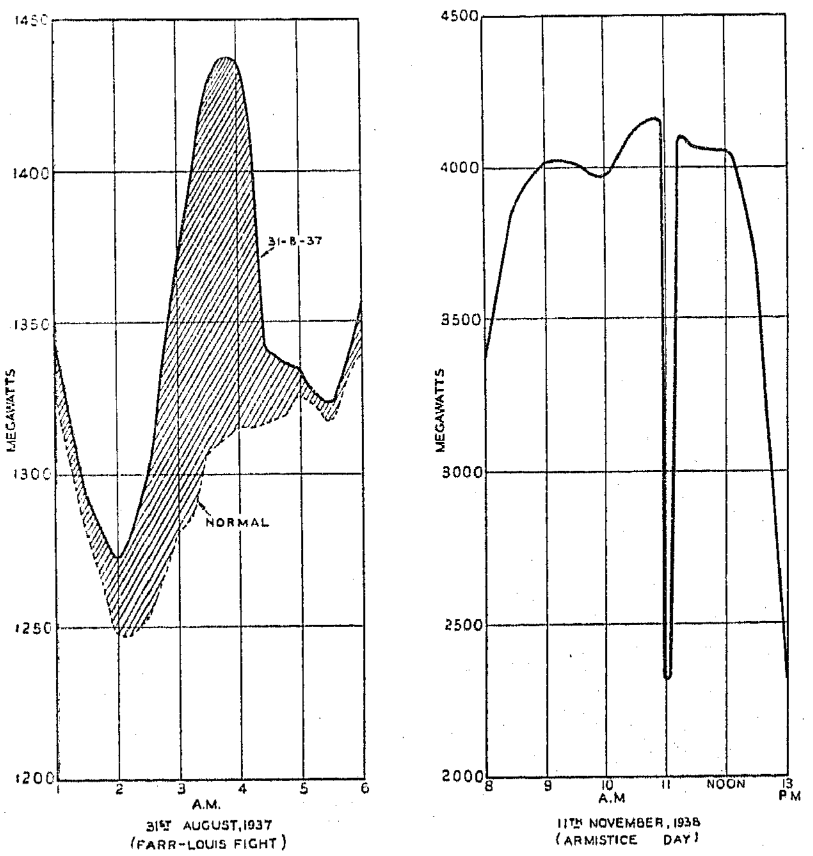

Fig. 7.—Grid-load effects of special events.

There is no doubt that the maintenance of a high standard of frequency control is a valuable safety precaution for meeting emergency conditions.

It is appropriate here to refer to a service so far rendered by power interests free of charge, namely the provision of electrical time. To the great majority of users the present standard of time-keeping is adequate, and the use of synchronous clocks has consequently extended very rapidly. There are, however, certain users who would like a higher degree of accuracy, and it must be made clear that the primary objective in operating power systems in this country is continuity of supply; the second is economy of production; accuracy of time-keeping is relatively not nearly so important, and no statutory requirement whatever charges the Board or any other authorized undertaker with the duty of time-keeping.

Fortunately for time-users, however, maximum efficiency of production, constant frequency and correct time-keeping are rigidly related by the fundamental principles of power production, and as we progress towards ideal operating efficiency we shall concurrently tend to satisfy even astronomers with the degree of agreement between Greenwich time and what we may justifiably call " Grid time."

As a word of warning, time-keeping, although now identical over hundreds of square miles, is not normally identical over the whole country, as the Grid is customarily operated in two or three sections. In such conditions there may be a slight divergence between the separated sections in phase and frequency, which might embarrass persons such as television experimenters wishing to depend on Grid supplies as a standard of exact time reference.

(c) System Stability

Actual experience of the electrical stability of the Grid under normal working conditions has been most reassuring. The Grid is not a simple transmission system transferring large blocks of energy over long distances from generating station to load centres, and its extended busbar characteristics favour stability; even when inter-area operation on a large scale is in force, there is no sign of instability provided the majority of the Grid lines are kept in service.

British alternators of more or less normal design have proved reasonably stable under Grid operating conditions, even during severe faults. Turbine governors have given practically no trouble, although in the case of some of the larger machines installed prior to Grid operation it is doubtful whether, if full load were thrown off, the running governor could keep the maximum variation in speed below the trip speed of the emergency governor. The throwing off of full load does not often occur; but if it does, every minute is valuable, and if the emergency governor operates, considerable inconvenience may be caused by the time and trouble required to bring the machine back to normal conditions ready for load. The difficulties involved are fully realized, but I feel sure that British manufacturers will not fail to find a satisfactory solution of this minor problem.

(d) Effects of Control on Efficiency

The first beneficial effect to be anticipated from the establishment of the Grid was a reduction in the plant capacity required to cover a given power demand. During the pre-Grid period the amount of spare plant to provide against possible breakdowns had been increasing steadily with the rising size of plant units, and the change in trend is clearly illustrated in Fig. 8. Fig. 2 showed the already large effect of this upon the capital requirements of the supply industry. Future plant extensions will be proportionate to the rate of growth of load, but savings under this head will continue, since at all stages of growth a smaller volume of plant is required under Grid conditions.

Apart from the saving in capital charges, the Grid

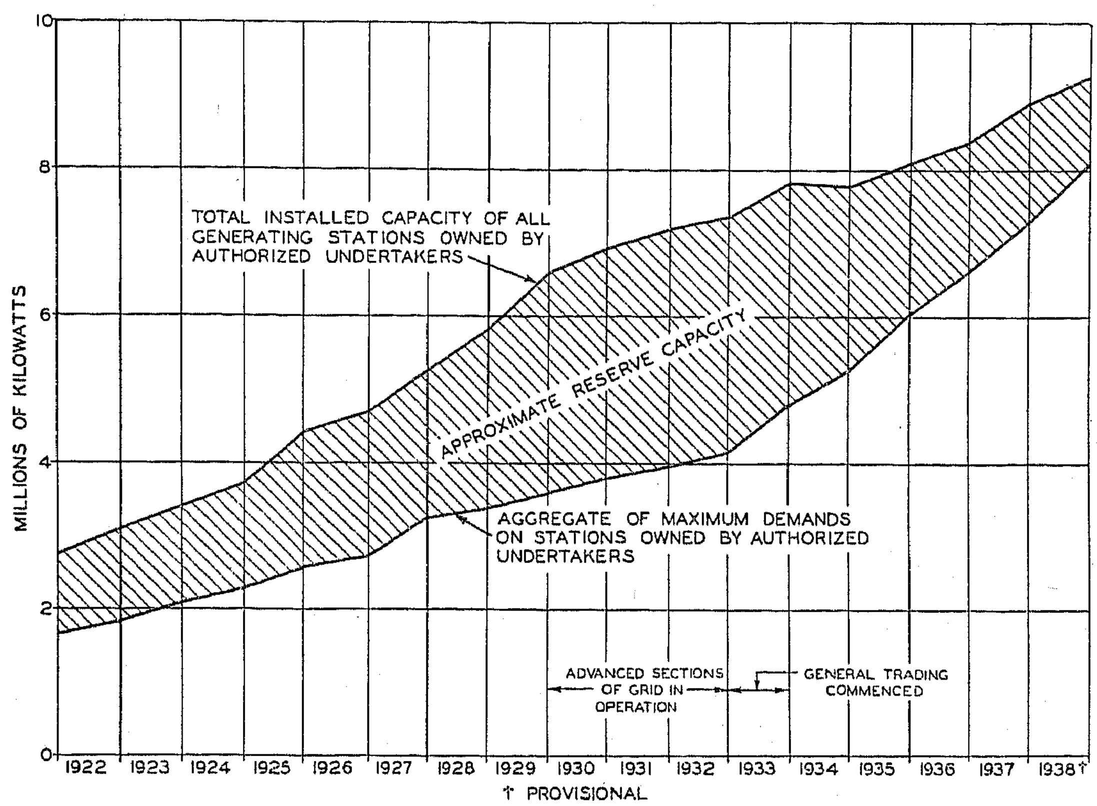

Fig. 8.—Effect of Grid on plant capacity.

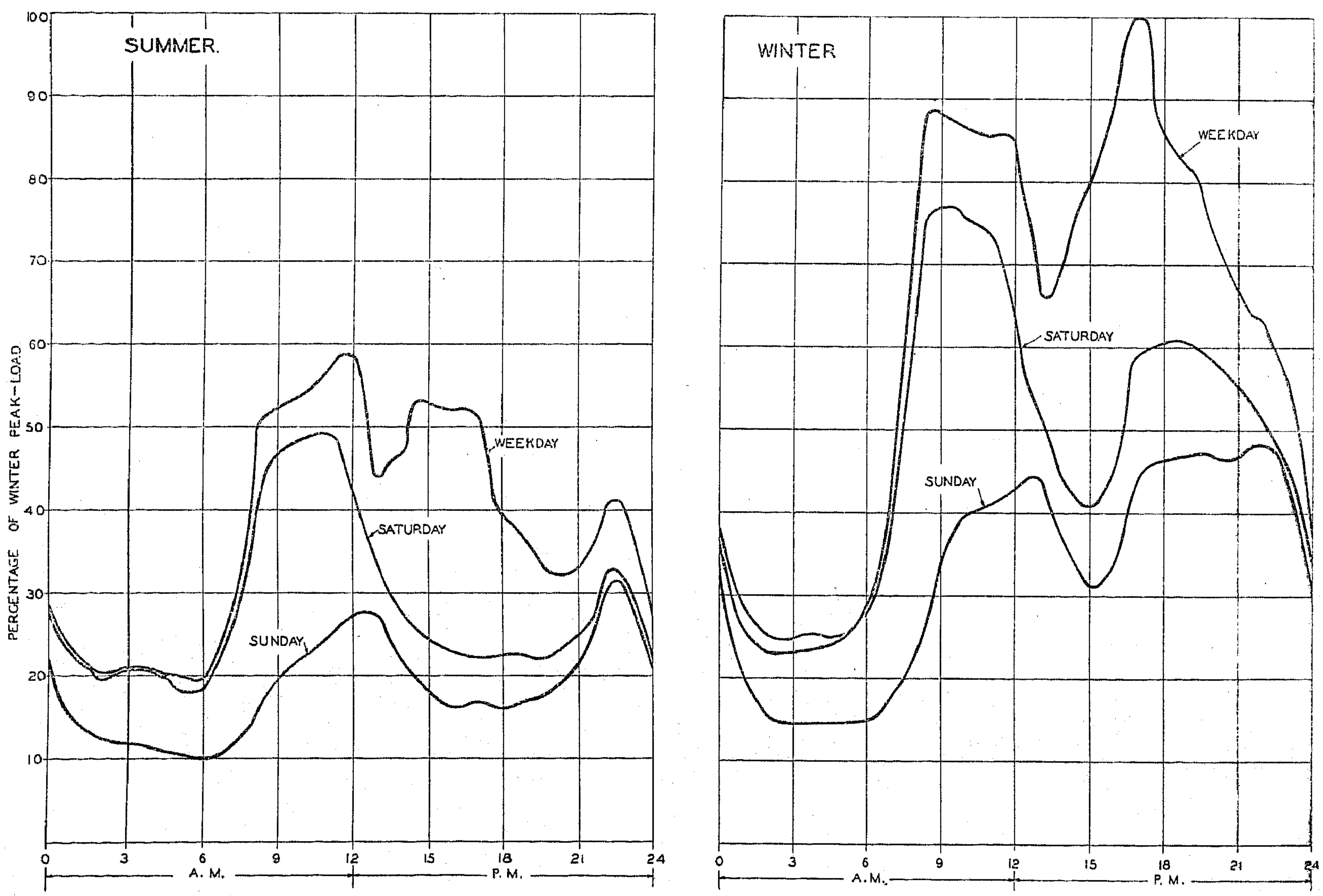

Fig. 9.—Typical load curves for Grid system.

makes possible the allocation of load in accordance with cost efficiency, enabling the selected stations most efficient from the works-costs point of view to be run for long periods and the least efficient to be relegated to peak-load duty. The scope for such allocation is indicated by Fig. 9. By control it was possible in 1938, for instance, for only 30 of the 171 generating stations under the direction of the Board to be kept running throughout the year, 14 of the most economical stations to supply 50 % of the total units generated for the Board, and 52 stations to be run for less than 2 400 hours.

The national effect of this re-allocation of load is shown by Fig. 10, in which the extent of improvement in the stations operating under the directions of the Board is also indicated, on a basis which makes due allowance not only for the energy used for auxiliary purposes in the generating stations, but also for losses in the Grid.

Unfortunately, the savings due to this increase in thermal efficiency have been largely offset by the rise in the price of fuel since 1935. Fig. 11 shows that the rise in price per ton at stations operating under the Board's directions has been more rapid than the rise in price to other home users of coal, and Fig. 12 well illustrates the artificial nature of the rise. The several scheme areas differ naturally in the various factors which affect fuel price, such as average distances from coalfields to generating stations, availability of sea-borne fuel, and so forth. These natural divergences were clearly expressed in the average price of heat in 1932. But by 1937 all areas, except Mid-East (M.E.E.) and South-East England (S.E.E.), were so closely grouped as to be almost indistinguishable upon a fairly open scale.

It will be seen from Fig. 13 that, but for the technical improvement brought about by the Grid and by normal evolution in design, a heavy general increase in the charges for electrical energy could hardly have been avoided.

Fortunately, other items of cost are more under the control of the supply industry and, measured as costs per unit delivered to authorized undertakers for distribution, the costs of production at stations operating under the control of the Board have fallen as shown in Fig. 14.

Before leaving the question of efficiency, I should

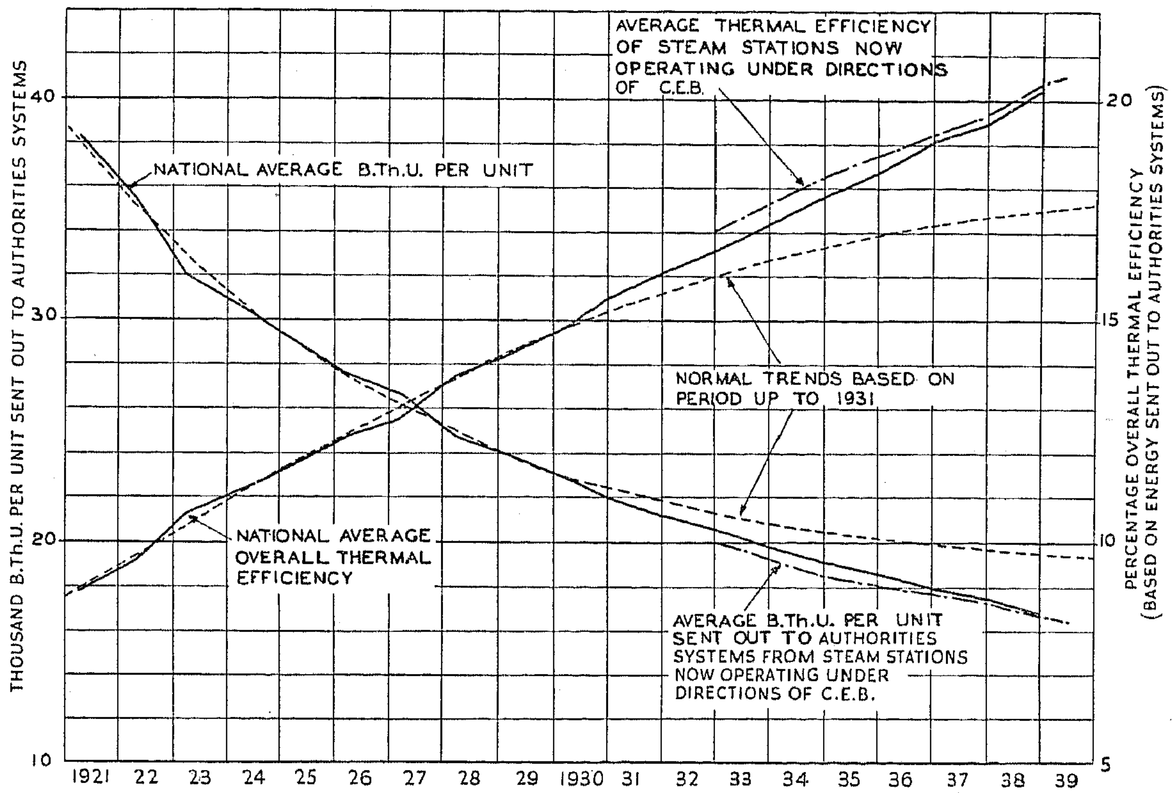

Fig. 10.—Effect of Grid on thermal efficiency.

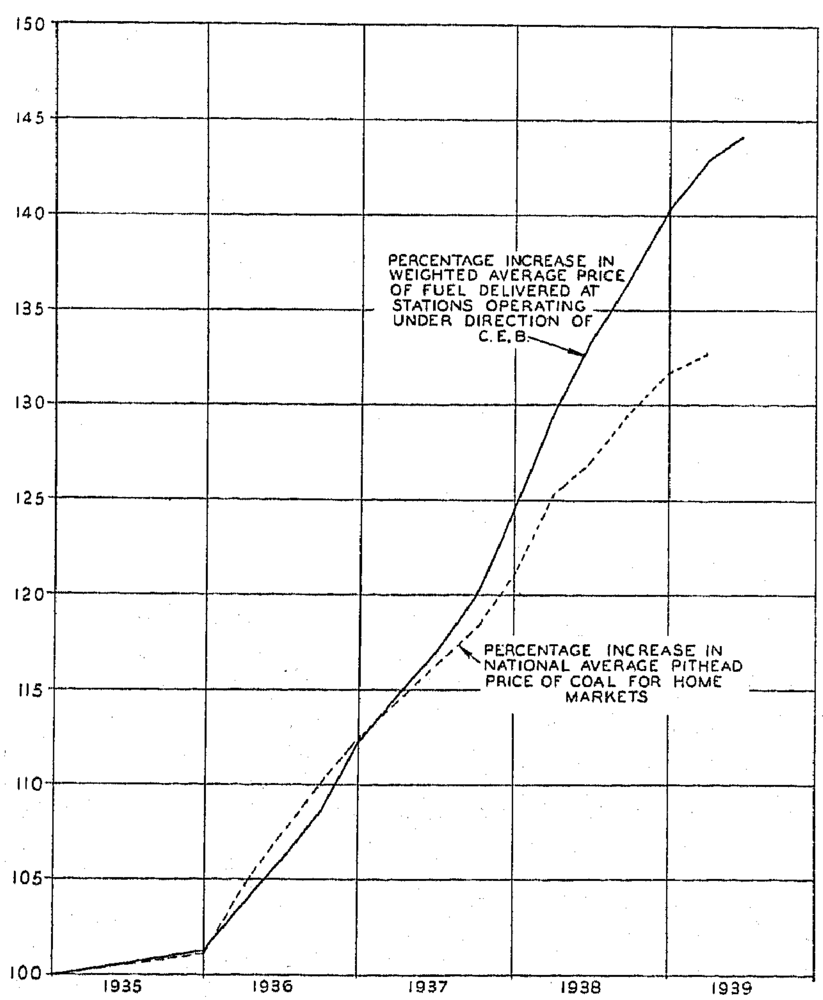

Fig. 11

NOTE.—12-monthly averages plotted at end of period to which they relate.

point out that there is room for closer examination by generating-station engineers of the factors which go to make up station performance. Under Grid control, the loading programme is largely determined by the relative cost efficiency at the several stations, in which the outstanding factor (apart from the cost of heat, which as we have seen is largely outside the control of the Board or the station owners) is thermal efficiency. Now the

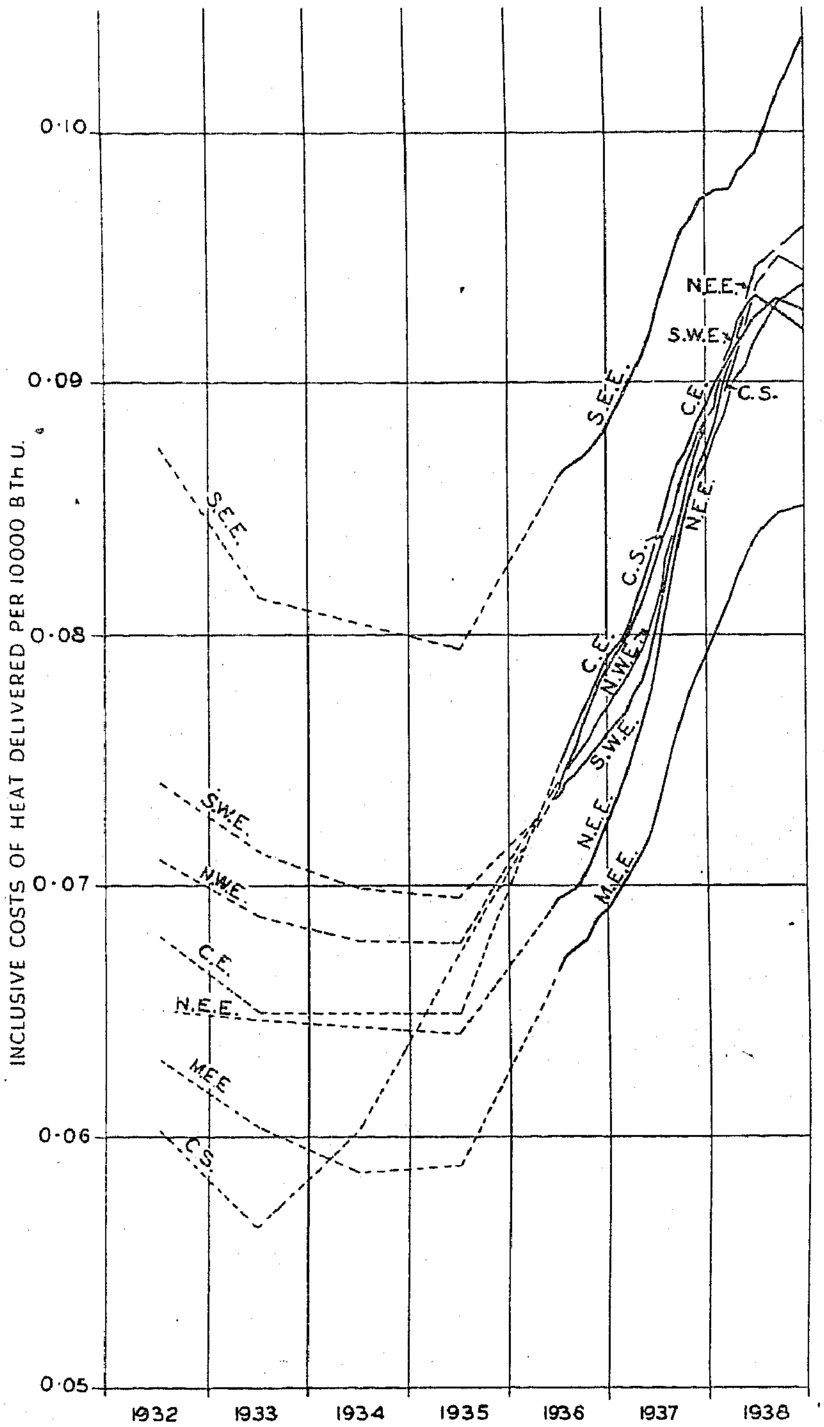

Fig. 12.—Twelve-monthly moving averages by districts (inclusive costs of heat per 10 000 B.Th.U.).

NOTE.—Cost of handling is included. Values are plotted at mid-point of 12-monthly period.

initial steam conditions and feed-water temperature chosen for a station immediately fix a definite upper limit to the ideal efficiency which can be approached by plant in that station; the design of the individual items of plant, and their relation to each other, determine a second limit—the maximum design efficiency of the station—while the loading and operation of the plant determine how far this maximum design efficiency is realized in practice. It is customary to express thermal efficiency as one overall figure, but as we are approaching the limiting ideal efficiency obtainable with steam generation, it might be well to separate out three factors—ideal efficiency, maximum plant efficiency, and operating efficiency.

(6) EXTENSIONS OF GENERATING CAPACITY

(a) Procedure

The onus of initiating all new plant proposals in connection with selected stations is now placed upon the Board. For the orderly fulfilment of this duty, plant-extension programmes are drafted by the Board in the spring of each year for each of the seven operating areas of the Grid. These extend for four winters ahead in the case of extensions to existing stations, and for five winters ahead in the case of construction of new stations.

The prediction of load growth over these extended periods is a matter of some difficulty and major importance. In preparing the plant-extension programmes, the Board obtain estimates from the individual undertakers of their probable load requirement over the period in question. These individual estimates are supplemented by independent area estimates made by the Board, based on the general principles of analysing separately the potentialities of each of the main classes of load, with allowance for probable future trade conditions.

After the estimate of the load to be met has been formed, a decision is then taken on the margin of spare plant to be provided, and in this connection the Board has the valuable assistance of the Consultative Technical Committee set up in each of the areas.

In deciding upon the margin to be provided, experience has shown it to be prudent to cover a compound risk made up of:—

(1) Potential error in estimating area load in normal weather conditions.

(2) Possible increase in area load due to abnormal weather conditions.

(3) Possible failure to reach anticipated total area generating capacity owing to delays in commissioning new plant.

(4) Potential failure or breakdown of generating plant after commissioning.

(5) Probable loss of capacity due to removal of boilers from service for routine maintenance.

(6) Prospective local circuit restrictions limiting the output from certain generating plant.

(7) Probable relation between reduction of load during summer months and capacity of plant then removed from service for maintenance overhauls.

The guiding principle in determining the location of additional generating capacity is to combine reliability of supply with maximum economy in the combined costs of production and transmission, and the advantages of locating stations at favourable generating sites have to be balanced against costs and hazards in transmitting their output to the load centres.

The general adoption of higher steam temperatures and pressures is rapidly diminishing the relative difference in cost efficiency between stations with abundant cooling water and those with cooling towers. Broadly speaking,

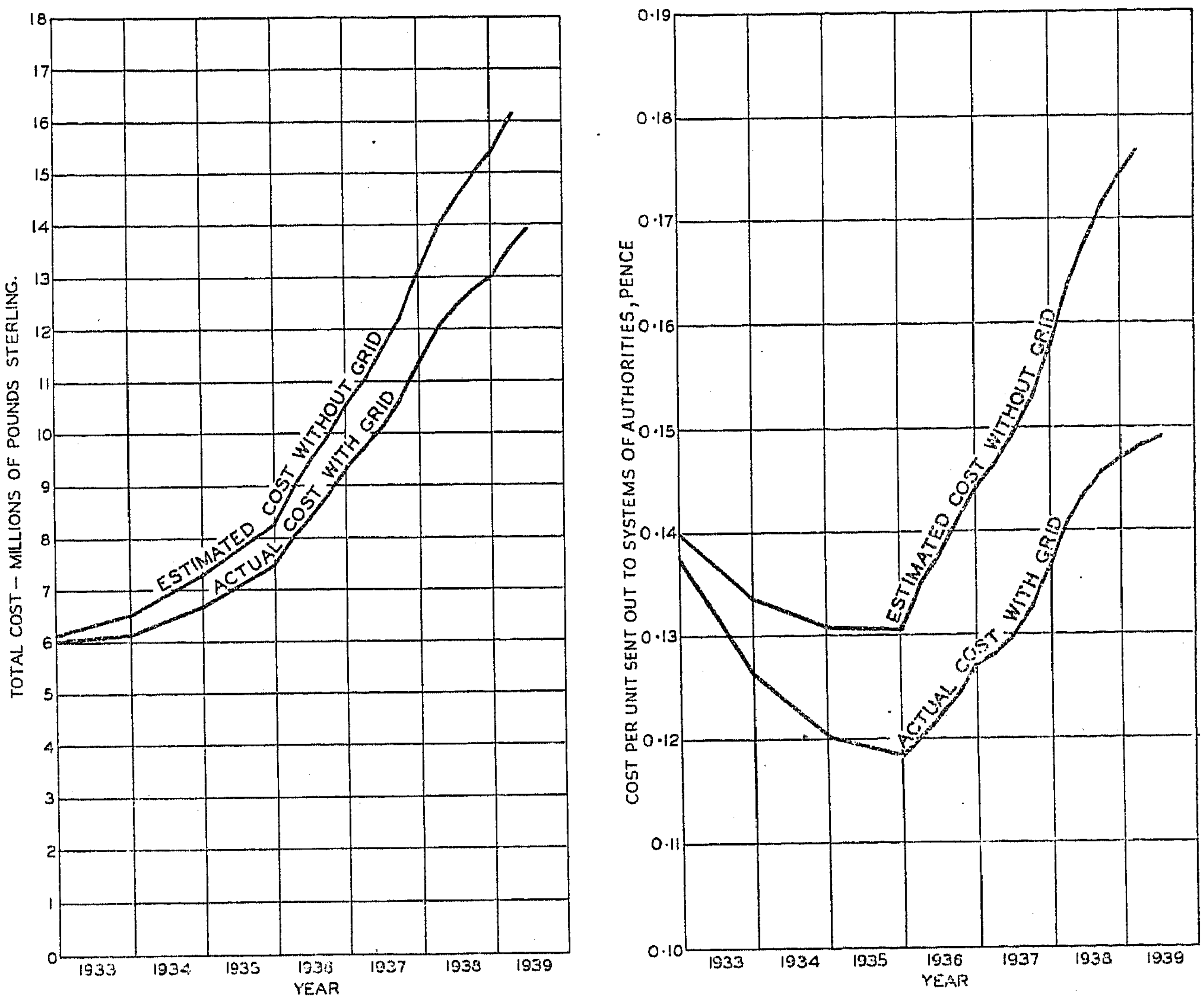

Fig. 13.—Cost of fuel delivered to all steam stations now operating under the directions of the Central Electricity Board.

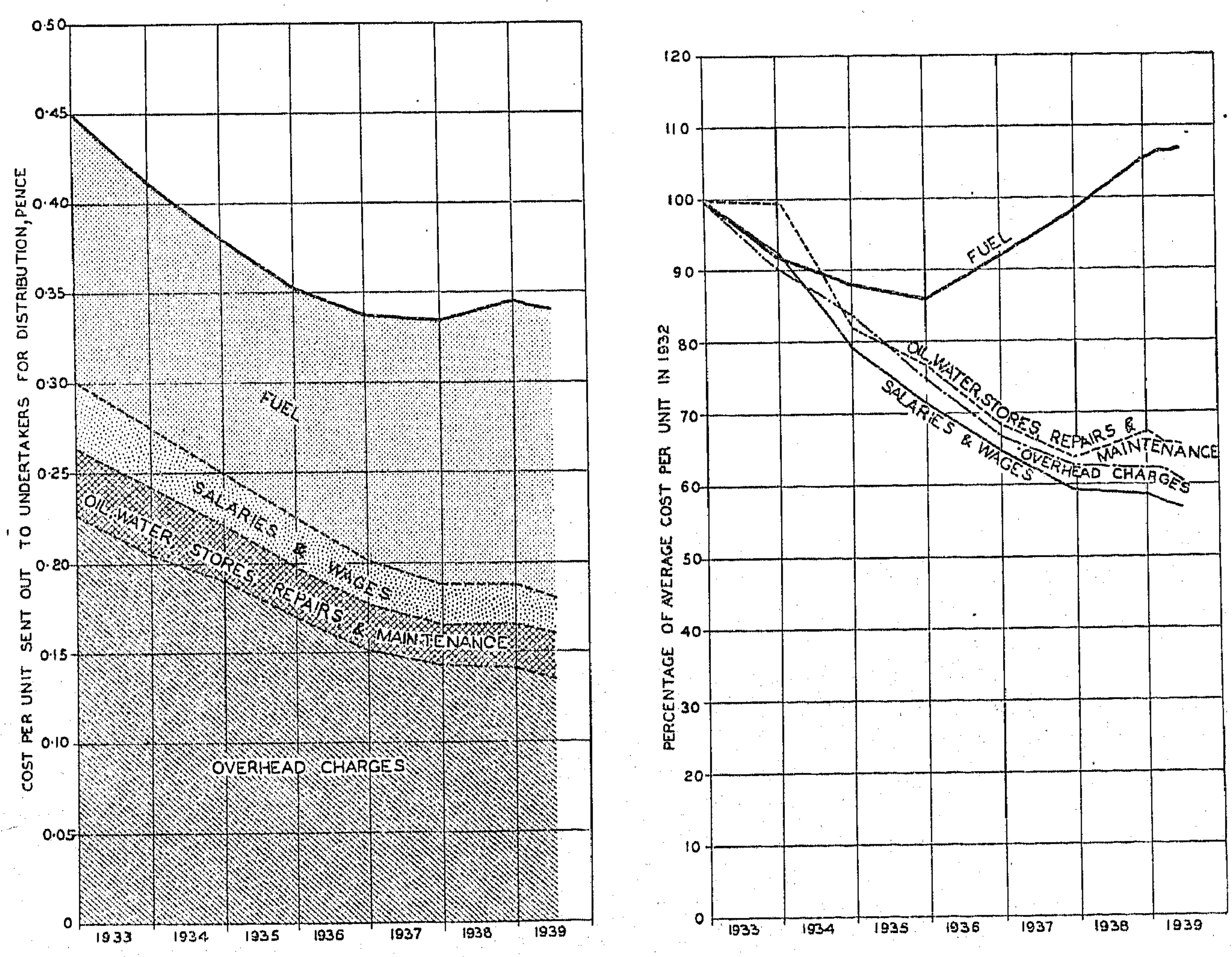

Fig. 14.—Average costs of production at all steam stations now operating under the directions of the Central Electricity Board.

NOTE.—For 12-monthly periods plotted at end of period.

riverside stations have the lowest capital costs, followed by cooling-tower stations, while stations on coastal estuaries have the highest capital costs owing to the expensive civil engineering work required. With modern high-efficiency cooling towers, re-cooled temperatures of 75°, 70°, and even 65° F. are possible in the average hygrometric conditions obtaining in this country of 51° F. wet-bulb temperature, when working on cooling ranges of 14 degrees down to 10 degrees F., and in these circumstances a cooling-tower station may be designed for an average annual thermal efficiency very little lower than that at a riverside site, enabling future plant to be more closely located in relation to load centres, with very substantial consequential savings in transmission.

To digress for a moment, I would commend to those engineers responsible for the design and construction of new stations the necessity for closer investigation of the factors which finally determine capital and other fixed costs of operation. Such costs appear to vary over a large range, which cannot altogether be explained by variations in site conditions. A comparison of the records of running economy and reliability does not by any means justify the apparently high relative costs per kilowatt of certain stations.

(b) Development in Plant Design

The Board have endeavoured to avoid any action tending to stereotype design and have done everything possible to encourage design development on the part of both manufacturers and users.

During the past few years considerable investigation has been carried out in order to establish in practice the thermal gain from a change in the steam cycle, and some very interesting plants are now in operation or under construction in selected stations.

Considerable developments have also taken place since 1927 in boiler design, but time does not permit of any adequate review of these, although mention must be made of the special types of forced and natural circulation boilers which are being tried out by authorized undertakers in this country at the present time. These developments would make very interesting papers by themselves and I hope that The Institution may have the benefit of such papers in the near future.

(c) Boiler Availability

The establishment of the Grid has drawn attention to the influence of boiler availability on capital and operating costs. There is a wide gap between the average availability of turbo-alternators and boilers, and every effort should be made to ensure better boiler availability and thus avoid capital locked up in the boiler house lying idle for long periods of the year.

Investigations have shown that where high gas velocities had been employed in the economizer and air-heater sections of the boiler, rapid fouling occurred with certain brands of coal, and in certain cases the pressure-drop increased by 10 % in under 400 hours' service.

In the more recent types of boilers, the adoption of larger combustion chambers, coupled with an increase in the amount of heat absorption by radiation in the combustion chamber and a reduction in the amount absorbed in the convection passes of the boiler, has led to some improvement in availability, and recent experience gained on a high-head type of stoker-fired boiler shows that after 2 500 hours' continuous service, during which 14 different brands of coal were used, it was still possible to obtain 25 % overload, although the gas passes had been cleaned by soot blowers only. This is a marked improvement, which I hope will be followed up by boiler designers and lead to still better results.

Table 3

NEW TURBO-ALTERNATOR CAPACITY ARRANGED FOR BY CENTRAL ELECTRICITY BOARD (FROM 1927 TO 1942)

*Classification by size of sets**

Maximum continuous rating	No. of sets	Capacity of group at M.C.R.	Group proportion of total
MW		MW	%
20 and under	40	562·0	9·9
25 to 40	88 (68 of 30 MW)	2 626·0	46·4
45 to 60	38 (17 of 50 MW)	1 972·6	34·8
75	4	300·0	5·3
100 to 105	2	205·0	3·6
	172	5 665·6	100

Classification by Steam Conditions

Steam		No. of sets	Capacity of group at M.C.R.	Group proportion of total
Pressure	Temperature			
Lb./sq. in.	° F.		MW	%
150 to 300	600–800	23	483·25	8·7
315 to 450	700–850	65	1 962·45	35·3
500 to 650	800–900	67	2 780·90	50·0
1 235 to 1 350	825–950	4	224·00	4·0
1 900	930	2	113·00	2·0
		161	5 563·60	100

* The particulars given in this Table include those relating to water-power equipment.

(d) Treatment of Flue Gases

Systematic and large-scale investigation in this country into the problems of comprehensive flue-gas treatment only dates from 1927, when the first definite requirement to remove sulphur compounds from flue gases was imposed on an electricity supply undertaking. Two large existing selected stations have already been required to be equipped with sulphur-extraction plant, and in some other cases provision has had to be made in the design for the subsequent addition of such plant if necessary.

When it is realized that the provision of gas-washing plant of the types now in use may increase the capital costs of a station by as much as £2 per kW, may add

some 0·02d. per unit to the works costs of generation, may increase the consumption of energy in auxiliaries by about 1 % of the generated units, and may reduce boiler availability by about one-sixth, it will be seen that the addition of the gas-washing equipment at present available constitutes a serious burden on the industry. Here is a subject giving ample scope to the engineer and chemist, for there is urgent need for investigation and research, with the object of developing systems which will ensure some commercial return on combustion by-products commensurate with the costs involved in gas-washing.

(e) Plant Standardization

It is obviously desirable, in the interest of the supply industry, to secure the maximum standardization of plant sizes compatible with continued development in design.

Tables 3 and 4 show that a considerable degree of standardization has in fact been made possible under the national scheme by active co-operation between the Board, the authorized undertakers, and the manufacturers. It will be seen that 30-MW and 50-MW sets are the most favoured sizes, and that the preferred steam conditions have been 500–650 lb. and 800–850° F., followed by 315–450 lb. and 750°–800° F. While some 16 % of boiler capacity comprises units of under 125 000 lb.-per-hour rating, largely low-pressure plant installed in the early years of Grid operation to supply steam to the then existing excess turbine capacity, nearly 85 % consists of boilers in excess of 125 000 lb.-per-hour rating and 68 % is in excess of 150 000 lb.-per-hour rating.

Table 4

NEW BOILER CAPACITY ARRANGED FOR BY CENTRAL ELECTRICITY BOARD (FROM 1927 TO 1942)

Classification by Size of Boilers

Maximum continuous rating	Number of boilers	Pressure	Temperature	Capacity of group	Group proportion of total
1 000 lb./hr.		lb./sq. in.	° F.	1 000 lb./hr.	%
0– 80	38	200/400	630/770	2 835	4·3
81–100	28	235/400	650/820	2 740	4·1
101–125	42	200/675	690/875	4 942	7·5
126–150	74	395/670; also 5 at 1 400/960	725/875	10 740	16·2
151–187·5	76	325/650	760/875	13 468	20·4
188–225	55	360/670; also 2 at 2 000/940	720/850	11 347	17·2
226–275	50	370/650; also 2 at 2 000/940 and 2 at 1 235/825	735/875	12 800	19·3
276–350	16	375/675	780/925	5 051	7·6
Above 350	5	610/1 420	850/965	2 225	3·4
	384			66 148	100·0

Classification by Pressure

Pressure	Temperature	Number of boilers	Capacity of group	Group proportion of total
lb./sq. in.	° F		1 000 lb./hr.	%
150– 300	650–730	25	2 120·0	3·2
301– 450	650–825	170	25 222·0	38·1
451– 599	750–850	16	3 112·5	4·7
600– 675	800–925	160	32 423·5	49·0
1 235–1 420	825–965	9	2 350·0	3·6
2 000	940	4	920·0	1·4
		384	66 148·0	100·0

(f) Hydro-electric Selected Stations

The foregoing refers to steam-driven generating plant at selected stations, but the Grid made possible the development of the Galloway water-power scheme, which, although only accounting for little more than 1 % of the energy consumed in Great Britain, is of much

technical interest. The natural water-power resources of the area could not have been effectively utilized in the customary way, and the Grid gave exactly the outlet required for the potential power. The scheme was formulated by the late William McLellan, and it is greatly to be regretted that he did not survive to witness the successful culmination of a scheme which, in all essential respects, was of his own creation.

The scheme consists of five stations—Kendoon, Carsfad, Earlstoun, Glenlee and Tongland—which act principally as peak-load stations supporting the thermal stations in Central Scotland and North-West England, but also provide the energy required for local purposes. They have a total installed capacity of 103 250 kW and were designed to generate 180 million units per annum, but in 1938 they generated 280 million units. With the increase in price of coal, the scheme is more than ever a welcome and highly economical contribution to the generating capacity of the country.

(g) Remodelling of Older Stations

The national scheme as it now stands differs in one important particular from the original proposals. Whereas the Weir Committee contemplated that national needs could be met by a total of 58 selected stations, the Board found that certain stations not suitable for selection had some residue of useful economic life in association with the Grid, and in 1938 the Board had under direction the operation of no less than 171 stations, including 137 selected stations. In present circumstances the retention of these additional generating stations constitutes an asset of material value from a national point of view, since, apart from defence considerations, with spreading urbanization suitable generating sites are increasingly difficult to secure.

Not all the sites still retained are suitable for redevelopment, since present-day needs have outgrown the capacity or suitability of the sites, but most of the older stations will still continue to give service under the Grid scheme. They have fulfilled useful peak-load functions up to now, and as the existing equipment is amortised many are being—and will be—reconstructed to give a good account of themselves in years to come.

With this end in view, a careful investigation of the site conditions at each station is in progress, it being most important so to plan reconstruction as to avoid any fall in capacity and yet to ensure that any extension shall form part of a comprehensive ultimate scheme of development. In many cases it has already been found possible, by the purchase of additional land, to envisage modelling the station up to three or four times the original designed capacity.

(h) New Stations

Even when advantage is taken of the re-development possibilities of all existing sites, the rate of growth of load is so rapid that already the Board have made definite arrangements for the provision of 12 new selected stations. If current trends continue, in the years that lie beyond 1942 many more new stations will be required, giving ample scope to engineers of the future for further development in the "scientific art" of economical electricity production.

(i) Total Capacity

The total national installed generating capacity in 1927 was approximately 5·2 million kW. Since that date there has been installed, ordered, or approved for installation up to the year 1942, under arrangements made by the Board, a total of some 5·7 million kW, involving a capital expenditure of approximately £81½ millions, which is almost three times the capital expenditure on the original Grid.

It will be seen that arranging for the provision of additional generating plant is now one of the major activities of the Board, and will be of increasing importance until such time as the rate of growth of demand upon the supply industry slackens.

It is not too much to say that the Grid has brought about a revolution in the outlook regarding the provision of new generating equipment. Indeed, the co-ordination of generating plant development may well prove ultimately to be the greatest of the contributions of the Grid towards the advancement of the supply industry. Previously, new generating facilities were provided piecemeal as required by the load increment of the individual undertakings, and the size and type of set were more or less rigidly determined by local load prospects in the years immediately ahead.

Within those limitations, a steady increase in plant efficiency was ensured by the consent of the Electricity Commissioners to the installation of new plant, the progressive outlook of the responsible engineers, and the healthy rivalry between the manufacturers of different types of plant. While these factors continue to play their part, the establishment of the Grid has introduced a completely new factor, since it enables planning to be carried out on a radically wider and more logical basis than was possible under isolated operation.

(7) CONCLUSION

The success from a national viewpoint which has been, and is still being, achieved by the Grid policy is a great tribute to the co-operative spirit prevailing in the supply industry, in which all the authorized undertakers concerned have played a worthy part. With their loyal co-operation, a state of organization has already been accomplished on the generation side of the industry which is without parallel in any other country of the world.

I cannot close this survey without paying my meed of tribute to the work of so many scientists who have helped in the creation of this national asset. The extension of applied science into the various industrial laboratories and Research Associations has done much to solve our problems, and some of the finest brains in the country are now engaged in such centres. To such workers the electrical industry owes a real debt of gratitude.

Looking back on this brief review of the progress made since 1927 with the Grid scheme, and of the outlook for the future, I am satisfied that we have in our national electrical industry all the components required to provide the user of electricity with the best possible service. I see no easy path to completely trouble-free electrical service, nor do I fail to realize that the supply industry has technical and organization problems which still await

solution. But I do see much scope for the labours of adaptable and imaginative engineers. The part to be played by The Institution, in improving and developing the personnel and equipment required by our great industry and in furthering the cause of international engineering co-operation, is both onerous and honourable, and it will be my pleasure and privilege to assist in the task during my period of office as President.

I enter upon that period at a time when, unfortunately, science is debased for war purposes, instead of promoting goodwill and friendship between nations. But although others may for a time disturb the pursuit of knowledge, scientists throughout the world form a great brotherhood, united by a common aim, a common quest for knowledge. Kingsley long ago expressed the democratic basis upon which this fellowship is founded. "If," he said, "you want a ground of brotherhood with men, not merely in these islands, but in America, on the Continent—in a word, all over the world—such as rank, wealth, fashion, or other artificial arrangement of the world cannot give and cannot take away, join the freemasonry in which Michael Faraday, the poor bookbinder's boy, became the companion and friend of the noblest and most learned upon earth, looked up to by them not as equal merely, but as teacher and guide, because philosopher and discoverer."

TRANSMISSION SECTION: CHAIRMAN'S ADDRESS

By FREDERICK W. PURSE, Member.*

(*Address received* 15*th October*, 1939.)

To have been elected Chairman of this important Section of our Institution is an honour for which I must, at the outset, express to the members my deep sense of appreciation.

More particularly is it gratifying to me to have been entrusted with this responsible position inasmuch as I was able to play some small part in the "behind the scene" negotiations which resulted in the former Overhead Lines Association being reorganized and reconstituted to make its powerful contribution, as the Transmission Section, to the work of The Institution.

I feel it will not be out of place for me to put on record the untiring efforts of the then President of the Association, Mr. A. L. Stanton, in the negotiations to which I have referred. I am quite sure that Mr. Stanton must review with sincere satisfaction the successful outcome of his great task and, in conjunction with his predecessors, regard with pride the work of this Section as the development of the Association of which they were such successful pioneers.

Little did I think, however, that it would fall to my lot to occupy the honoured position of Chairman, and at a time almost coincident with the outbreak of another catastrophic war in which our own and other great countries would be involved. Transformation, as we refer to it in the work of our Section, pales into insignificance compared with the transformation to which we have been committed in our daily lives by the war.

Any thoughts and suggestions which it would have been my privilege to submit to the Section in the time-honoured Chairman's Address must similarly be tempered by the vastly changed conditions which war brings. I must frankly confess to feelings of distraction and uncertainty in approaching the task: first, because one's daily activities have become so exacting on account of the topsy-turvydom that has occurred to our normal routine; secondly, because the past is past to a degree which few of us are scarcely yet able to realize; thirdly, because the future is a "blackout" which all our imagination cannot pierce at the present time; and fourthly, any matters—however attractive to the members—which might have any bearing on our national safety and interests must be suppressed. I find myself, therefore, reluctantly compelled to restrict this Address to a general review of our position, with a few notes on some points that have come under my consideration from time to time.

The thoughts of all of us must, I feel, be persistently flying back to the last war in an attempt to measure the conditions which had then to be faced, how they were met, and how we set about re-establishing a new order of things so that the particular side of our industry in which we are interested could keep step in the march of electrical progress.

There is no doubt that in 1914 there was at our command, thanks to research—though limited at that time—and to the able efforts of our manufacturers, such developments that the transmission engineer was in a position to take full opportunity of distributing the supply which was becoming rapidly available at a lower cost of production, owing to improvements in design and the increasing efficiency of turbine and boiler plant.

This position was, in a degree, a fortunate one, as the enormous demand after the outbreak of war in 1914 on our supply systems, mainly for power purposes, taxed our resources to the utmost. Although it may be fairly claimed that the manufacturing and supply industries rose nobly to the occasion, the inevitable difficulties which occurred exposed what appeared to be various weaknesses in the general organization of the supply industry throughout the country. Equally it exposed the fact that electricity supply was an essential public service, and that if there were any weaknesses they must be removed.

The many inquiries into and reports on the matter, and subsequent Acts of Parliament embodying the recommendations of these inquiries and reports, are now so well known to all members that it is unnecessary to refer to them in any detail. The conservation of coal was the hare which started the legislative hounds on the track, but the electricity course was the only one on which the chase was so assiduously pursued.

The Electricity (Supply) Act 1919 was the moribund product of Parliamentary effort, followed by a further Act in 1922 to make it effective. Even this additional legislative blood transfusion failed to produce the results aimed at by the promoters. More inquiries and yet another Act followed in 1926, and still further amending Acts in 1928, 1933, 1935, and 1936. As the present war has intervened and thereby caused a suspension of further legislative activities, the pause enables us to review the outcome of these Parliamentary efforts since the last war.

They have given us as outstanding features the Electricity Commissioners and the Grid. How far, however, has the basic principle, viz. the conservation of coal, been achieved beyond what would have been achieved in the absence of legislation? If conservation of coal has been achieved, has the total cost of securing this achievement, including the loss to the coal-mining industry, been justified? Each of us may have his own opinion, but the "man in the street" who pays says "No!"

Linked up with this question is that oft-used, misused and abused quotation from the 1919 Act, viz. "a cheap

* London and Home Counties Joint Electricity Authority.

and abundant supply of electricity." Let me once more state that these words were employed solely in connection with the establishment of Joint Electricity Authorities, when their duties were stated to be " To provide or secure the provision of a cheap and abundant supply of electricity."

The extent to which this direction of Parliament has been frustrated by all vested interests needs no elaboration on my part at the present time. But I do want to point out that even persons who should be better informed have repeatedly applied this quotation as being also the intention of the 1926 Act.

A careful study of that Act will show that not reduction of costs but prevention of increased costs was a major consideration. Both in regard to selected and non-selected station owners, special provisions were inserted to ensure that the cost to those owners for their supply should not be greater than if the Act had not been passed; there is no exalted suggestion of a " cheap and abundant supply," but a desperate anxiety to guarantee no increase in cost.

The extent to which this guarantee has matured " but for the passing of the Act " is not for me to dwell upon here. But I cannot refrain from mentioning the decision of the Electricity Commissioners, recently conveyed to the Chester Corporation, that an extension of generating facilities cannot be permitted although it was demonstrated that this was the more advantageous method of the Corporation's obtaining a cheap and abundant supply.

So that my references to the 1926 Act may not be misunderstood, I would add that I intend no criticism of the Central Electricity Board; on the contrary, I consider they are entitled to our genuine sympathy in being responsible for the administration of such an unpalatable and difficult Act. Likewise they are certainly entitled to our wholehearted admiration for the speed and efficiency with which they have done their job, their assistance to and co-operation with everyone concerned, and last, but not least, the great impetus and excellent technique which they have given to our work as transmission engineers. We must, in all fairness, acknowledge what the Grid has given us, even if we are disappointed at what it has not given us or has perhaps taken away from us.

Equally important is a second question, viz. How far have the other difficulties been overcome in respect of which criticism was raised? Let me mention three only of such difficulties, although there are many others, (1) public control of all electricity supply, (2) purchase rights of local authorities, and (3) rural electrification.

In regard to (1) I do not necessarily mean nationalization or municipal ownership. We still have to-day, as at the end of the last war, municipally-owned and company-owned supply undertakings. I am not proposing to advance a case either for or against either type of operation, but simply to point out that no reform has taken place in this direction and that in my opinion uniformity can never be achieved where a public service is saddled with two such dissimilar types of ownership having to some extent dissimilar outlook.

As to (2), it will be remembered that the 1882 Act vested in local authorities the right of purchase of company-owned distribution undertakings after 21 years, this period being extended to 42 years by the 1888 Act.

Many complications have arisen owing to doubt as to the precise meaning of the Acts in regard to the terms of purchase, particularly in those cases where the area of supply has been extended. Purchase dates are frequently non-coincident, and the purchase rights of the extended areas are often in the hands of more than one authority. This particular subject bristles with a variety of problems, and the failure adequately to deal with it is, I consider, a serious reflection on those who took in hand the job of reorganizing our industry.

Coming to (3), the subject of rural electrification is one which has probably exercised the minds of the members of the Section more than any other, and I believe its difficulties were such as to necessitate the formation of our parental Overhead Lines Association. On this account, and as it will undoubtedly continue to be urged upon supply undertakings as their moral liability irrespective of the financial consequences, I may be permitted to make more than a passing reference to the subject.

It cannot be denied that, apart from very strong persuasive requests issued by the " powers that be," transmission engineers, in co-operation with the sales staff, have worked unceasingly to put up a good show in regard to rural electrification. The ingenuity that has been displayed in every direction in an endeavour to cater for the development of this side of our industry on an economic basis is worthy of all praise, but despite these efforts the results, particularly on the financial side, have not been encouraging.

In 1931 a paper* was read before this Institution by two members of the Electricity Commissioners' staff on " The Design of a Distribution System in a Rural Area," and there were set out in the paper three model schemes covering 400 square miles relating to an average density of population of varying degrees, viz. 150, 100 and 75 per square mile.

The authors' final conclusion from their consideration of the matter was as follows:—" With goodwill and co-operation, electrification can proceed on a sound financial basis, even in areas having average densities of population little above 75 per square mile."

Over 7 years have now elapsed, during which time one would have expected that the result of development and improvement in apparatus and materials would have been manifest, and as there is available precise information in regard to actual schemes it is useful and interesting to examine what the trend of events has been.

The actual schemes which I have in mind are those of the Norwich Corporation, Kirkcudbright County Council, Dumfries County Council, and the Bedford Corporation. I have taken the liberty of reproducing, from the paper referred to, the Table showing a " Résumé of the Principal Features of the Three Schemes," and have added similar information (as extracted from the 17th Annual Report of the Electricity Commissioners) for the four actual schemes already mentioned. The figures are set out in the Table on page 21.

Whilst none of the actual schemes has the same area as the model schemes, the densities of population are in

* E. W. Dickinson and H. W. Grimmitt: *Journal I.E.E.*, 1932, **70**, p. 189.

one case approximately the same, in another case above and in the other two below those of the model schemes, thereby giving an excellent basis of comparison, especially bearing in mind that the periods covered by the model and actual schemes are similar.

The outstanding feature of this comparison is that, after allowing for the preparatory period, the actual schemes still show a deficit (bearing in mind the cash contribution received by Kirkcudbright) as compared with the estimated profit under the model schemes.

Particular attention should also be drawn to the charge for bulk supply in connection with the actual schemes—if the higher charge of the model schemes had obtained, the deficits would have been still greater.

When the other factors referred to in the notes to the Table are taken into account, it needs no further elaboration on my part to justify the statement that rural electrification is not a paying proposition, at any rate on the basis of charges which have been demanded for this class of load.

It might be contended that with lower charges for retail supply a greater number of units per consumer would have been realized in the actual schemes and a better financial result obtained, but a detailed examination of all the figures would reveal that such a contention could not be sustained. Supporting evidence of this is to be found in the paper read before the I.M.E.A. Convention at Harrogate this year by Messrs. Robinson and Morland on "Some Practical Aspects of Electrical Development and Distribution."

Particulars were given in that paper relating to the rural area of the Liverpool undertaking; although classified as rural it has a density population of 430 persons per square mile over an area of 81 square miles. The charges for the supply to consumers obtaining in this area are lower than those assumed for the intensive development envisaged in the model schemes.

Despite these lower charges, together with exceptional facilities for the hire of apparatus and the full advantage of the Liverpool undertaking in assisting development, the figure of units sold per consumer in this particular rural area has, after 10 years, reached only 1 488 as compared with the total of 1 750 in the Model schemes after 6 years.

I do not intend my use of the word "only" in any disparaging sense as regards the work of Liverpool—it is a commendable achievement—but simply to emphasize that progress must necessarily be slow and that the price of electricity is not alone the determining factor.

My conclusion, therefore, is that if rural electrification is to be still more intensively developed it can only be done by a subsidy from somebody. Who this somebody is to be I cannot prophesy, but a study of the position shows that the great tracts of electrically-undeveloped rural areas are not generally associated with large industrial centres who would be best able to carry the subsidy.

I must, however, leave the problem for an after-war solution in the hands of those entrusted with the responsibility of tackling the subject when it has to be tackled.

These are the three outstanding matters which in my opinion require deep and serious consideration if Parliament does in due time consider further legislation to be imperative.

It may be that others will disagree with the importance I attach to these points and would add to them or replace them by different ones. If this be the case, then I would reply: "Let all matters be tabled in order of merit and be carefully examined without delay by an expert body able to put forward constructive and acceptable proposals so that they may go forward immediately the appropriate time has been decided upon."

Whatever may be the position and condition of our industry when the wished-for "peace" is declared, I have no doubt in my own mind that the people of our nation will, whether with a clearly defined criticism or not, press for the reorganization of our supply industry, and, as the House of Commons is the voice of the nation, it will be difficult to resist the public demand. It is vain to anticipate any reduction of pressure to obtain, by some kind of reorganization, ever-diminishing charges to consumers, who are in this matter apparently indifferent to economic laws governing costs and prices.

The supply industry should itself, therefore, get on with the job vigorously and drop all the internal quarrels of the past so as to avoid the danger of antagonism becoming more acute and closer to flashpoint, resulting in Parliament hurriedly stepping in and, as in the past, imposing a settlement satisfactory to itself but unsatisfactory to those mainly concerned.

In reviewing the technical side of our work I realize that there is little I can add under present conditions to the various subjects which have been so ably dealt with in the past through the medium of the able and interesting papers which have from time to time been read and discussed at our own Section meetings, as well as other general ones before The Institution.

Cables, transformers, switchgear, overhead-line work, and the host of other matters in which we are closely interested in our daily work, have come under review.

Immense and wonderful progress has been shown in each of them, and, indeed, the transmission engineer of 1914 would regard himself as a Rip Van Winkle if suddenly confronted with the transmission engineer of 1939.

The war will be a testing time for all the work and plans which have been carried out, and whether they come up to expectations or not remains to be seen.

Will the Grid interconnecting a few large power stations that generate the great percentage of our supply prove superior to the old régime of many smaller power stations with but minor interconnections?

Will our extensive overhead transmission and distribution prove more vulnerable to enemy air attacks than our underground systems, and which method will show itself superior in respect of rapid restoration of supply?

Will the damage to our transformers, switchgear and other apparatus, be greater with the greater power likely to be poured into any damaged part of the main systems from our concentrated supplies?

Will the results of attack from enemy aircraft and even our own defences call for a reconsideration of these and other general lines of development of the past few years?

How will the respective public utilities of gas and electricity come through the ordeal of a severe air attack,

since the old adage of "the survival of the fittest" may have an important bearing on the future progress of either of them?

These and many other questions that spring to the mind of all of us can only be answered when the struggle is over.

The answers may overwhelmingly demonstrate the strength and wisdom of present-day policy in regard to transmission and distribution, but the reverse may be the case and so we can only wait and see.

Whatever may be the task that fate has in store for us it will, I know, be accepted and carried through by all in that spirit of determination and service which has been so fully demonstrated in the past. We of the Transmission Section will be eager to do our part. Our eagerness should not, however, be stultified by restrictions on the financial side, and the charges for supply should not be depressed to such a degree as to necessitate our transmission and distribution systems being cramped to an extent which one might rightly regard as "penny wise, pound foolish."

I have always contended that electricity is a good

Table

Items	Model (6th year of operation)			6th year; 1936–37	5th year; 1936–37	5th year; 1936–37	7th year; 1936–37
	No. 1 (density 150)	No. 2 (density 100)	No. 3 (density 75)	Norwich (density 110)	Kirkcudbright (density 34)	Dumfries (density 54)	Bedford (density 204)
Area .. .. .. square miles	384	384	384	125	900	1 070	109
Inhabited houses	13 056	8 832	6 528	3 942	10 000	14 176	6 918
Number of consumers	9 530	6 446	4 765	2 615	3 464	7 508	5 391
Bulk supply .. .. .. kW	9 746	6 592	4 873	—	—	—	—
Bulk supply .. thousands of units	19 638	13 282	9 819	—	—	—	—
Total units sold to consumers, thousands	16 678	11 280	8 339	1 353	2 749	7 592	15 068
Total revenue from sale of current £	95 900	64 870	47 950	12 317	28 404	60 241	54 325
Total revenue per unit sold .. pence	1·38	1·38	1·38	2·18	2·48	1·90	0·86
Total revenue per consumer .. £	10·06	10·06	10·06	4·71	8·19	8·05	10·07
Total costs .. .. .. £	84 865	61 675	46 965	15 295	28 390	60 328	56 748
Total costs per unit sold .. pence	1·22	1·31	1·34	2·71	2·47	1·90	0·90
Capital expenditure .. .. £	300 500	239 000	188 000	117 982	166 234	405 258	283 298
Capital expenditure per sq. mile £	782·6	622·5	489·7	943	184	379	2 599
Capital expenditure per consumer £	31·53	37·08	39·46	45	48	54	52·5
Units sold per £ of capital	55	47	44	11·4	16·5	18·7	53·1
Capital per 1 000 units sold .. £	18·02	21·19	22·55	87·2	60·4	53·3	18·8
Capital charges:—							
Interest at 4·75 % .. .. £	14 170	11 270	8 865				
Sinking fund at 3 % .. .. £	8 950	7 115	5 600	8 264	11 048	23 333	20 507
Interest on working capital .. £	800	540	400				
Capital charges per unit sold .. pence	0·344	0·403	0·428	1·48	0·96	0·73	0·32
Total annual expenses, other than cost of bulk supplies .. .. £	36 825	29 185	22 945	12 725	21 709	41 946	34 977
Total annual expenses per unit sold, pence	0·530	0·621	0·660	2·25	1·89	1·32	0·55
Load factor on bulk supplies .. %	23	23	23	—	—	—	—
Units sold per consumer	1 750	1 750	1 750	517	793	1 011	2 795
Revenue balance on year of account, £	11 035	3 195	985	Deficit 2 978	14	Deficit 87	Deficit 2 423

Notes:—The Model Schemes are based on bulk supply at £3 5s. per kW + 0·2d. per unit.

The Model Schemes do not include any provision for installation and apparatus on hire. The four actual schemes provide for installations and apparatus on hire and hire-purchase.

Norwich.—Bulk supply £2 18s. per kW + 0·135d. per unit. Certain charges are apportioned from the total costs of the whole undertaking.

Kirkcudbright.—Special rate for bulk supply from Galloway Water Power Co., together with cash contribution of £2 537.

Dumfries.—Special grant from Unemployment Grants Committee and suspension of sinking fund in respect of certain items of capital expenditure.

Bedford.—Bulk supply £2 15s. per kW + 0·1846d. per unit. Substantial power loads to brickworks. Certain charges are apportioned from the total costs of this undertaking.

Bedford, Norwich, and Dumfries, all received Government subsidies.

service and well worth a fair price, and yet it seems to have been singled out in distinction to all other commodities and services as the subject of attack from every quarter with incessant demand for cheaper and still cheaper rates.

This attack is evidence, of course, that the public want electricity in preference to its rivals and hope to have all the advantages which electricity offers without paying for them.

Have we ever witnessed the same continued attacks on the charges for water, gas, oil, coal, or even cigarettes, newspapers, bread and other general commodities?

Why, even in the case of transport, where road transport has been supplanting rail transport, the efforts have been concentrated more towards protecting the higher rail transport charges than to reducing them.

I feel that, goaded on by a selfish public, we have competed too much amongst ourselves in reducing charges, and that this has prevented us from making the necessary provision in gold and copper for a rainy day—and, perhaps I should add, for a frosty day.

In order to meet the financial position, we have as transmission engineers often been compelled to put down only a minimum size of mains, transformers, switchgear, and such like, omitting, where otherwise desirable, duplicate or interconnecting mains and other apparatus, with consequences well known to us all.

Let us have a sufficient reserve in the safe as well as in the ground so that we can endure even the coldest of cold snaps without a shiver.

We are now once more at the parting of the ways; many of us have gone through the period of one great war with a subsequent period of interesting and intensive development even greater than that which the most optimistic forecast. We are now in the throes of probably an even greater war, and what will be the aftermath and its repercussions in the next quarter of a century in regard to the transmission and distribution of electricity will doubtless provide many interesting topics for my successors in office.

One word in conclusion in regard to this, the Transmission Section of our Institution. Its membership, now closely approaching 1 700, does not include all those members who are entitled to be attached to the Section. In looking through the list of members I observe the omission of a number who, I know personally, are qualified for inclusion. It may be due to indifference, but more likely to a misapprehension that members are automatically attached to the Section by reason of their occupation. This, of course, is not the case and, whilst there is no additional cost to any member by reason of participation in any Section, it is necessary for application to be made on the prescribed form by each member qualified for and desirous of being included in the Section membership.

As my reference to this matter may not reach all who should be in this Section, I know I can rely upon the always helpful co-operation of our friends—the electrical Press—in giving prominence to the point in the most appropriate way.

The papers read before the Section, and the discussions thereon, are of the highest order, and the time and trouble taken by the authors in preparing them deserves the maximum support and encouragement from the members.

Whatever it may be possible for me to do under existing restricted conditions to achieve this end and to further the interests of the Section, will be an honour and duty of which I shall be especially mindful during my year of office.

WESTERN CENTRE: CHAIRMAN'S ADDRESS

By T. E. ALGER, Member.*

"A NOTE ON CURRENT DEVELOPMENT"

(*Address delivered at* CARDIFF *7th October*, 1939.)

In thinking over the subject matter of this Address, I have examined the published observations of other Chairmen of the Local Centres and I find that their authors, without exception, have confined their attention to subjects with which they were intimately familiar. And what better examples could I follow than those provided by my predecessors ? I am an electrical installation engineer, and it is to installation and cognate topics that I propose to confine the greater part of my observations.

First, however, I should like to pay tribute to the striking reorganization of our national scheme of electricity supply that has followed the prolonged work of the Electricity Commissioners and the Central Board. I know that electricity-supply engineers do not hesitate to express very pointed criticism of the national system of interconnected generation that has been set up in this country, and of the prospective reorganization of distribution. The fact remains, however, that the work of the Commissioners and of the Board has been of the greatest possible value to electricity consumers at large, and therefore to the electrical installation engineer, whose main purpose is to maintain the closest possible touch with all classes of consumers and prospective consumers of electrical energy. Much, however, remains to be accomplished in at least three important directions. In the first place we require the greatest possible attention to be given to the development of our rural supplies; in the second place the need to push ahead with the standardization of our voltages and frequencies is only too clear; and in the third place some measure of national standardization of our tariffs is a matter of supreme importance from a development point of view.

So far as rural supplies are concerned, it is apparent that the country is approaching a second industrial revolution. It is no longer necessary for factory plants to crowd round our coalfields, as was essential for economic reasons only a few decades ago. It is equally clear that political considerations will apply some type of limit to the future expansion of our crowded urban areas. Modern cities and industrial areas are far too large as it is; but, fortunately, the cure is at hand. National electric power transmission makes the rural factory not only commercially feasible but eminently desirable from the standpoints both of health and of national safety: and it is for this reason that I have placed the intensive power development of our country areas as the first item on my list of really urgent reforms.

It has been shown over and over again—and notably by the contribution on "Rural Electrification" made to The Institution recently by Mr. J. S. Pickles†—that comprehensive rural electrification schemes providing supplies not only to small centres of population and industry but also to dwellers in isolated farms, country houses and small groups of cottages, can be carried out with full commercial success. A financial policy in which losses, or narrow margins of profit, are balanced against the increasing returns of later years can be adopted with safety because the ultimate success of rural electrification is definitely assured. Mr. Pickles suggests a 10-year basis, and while it cannot be expected that such schemes can provide for both interest and depreciation from the moment of their inception, it is to be expected that a self-supporting basis will be reached in roughly 5 years.

A cheap supply of electricity is important, but it is equally important that an adequate supply should be available, even if it does mean that the ultimate success is delayed. In all commercial undertakings the rough has to be taken with the smooth, and much more could be accomplished in rural electrical development if greater courage were shown by those who control the financial policy of electrical undertakings. In rural areas the utmost use should be made of surface-wiring distribution in built-up areas, while adequate assisted wiring schemes—in which electrical installation engineers are capable of playing a very large and effective part—are essential to success.

Coming now to my second urgent need—namely the utmost possible standardization of voltages and frequencies—it is evident that no arguments of mine are required in support of such an essential simplification of our national supply arrangements; and it must be equally confessed that very real progress has been made during recent years to achieve this much desired reform. On the other hand, commercial difficulties occasioned by voltage variation, etc., continue to hamper all electrical installation engineers engaged in power work in different parts of the country, and anything that can be done to expedite this essential unification of our electricity-supply arrangements should enjoy our cordial and persistent support. The more quickly we can abolish the mistakes occasioned by the individualism of the past, the better will it be for all concerned.

One aspect of the future in connection with the development of electricity supply appears to me to be the necessity of giving more practical consideration to tariffs. There have been a number of papers in the *Journal* and the electrical Press generally, on the question of standardization of tariffs, although, after some 12 years of operation of the Grid, on the generation side due attention has been given to the principle of standardization of rates, etc., in connection with charges to

* Messrs. R. Alger and Sons, Ltd. † *Journal I.E.E.*, 1938, **82**, p. 333.

the many supply undertakings and works who purchase from them, yet little seems to have been achieved with relation to the standardizing of tariffs. To me there does appear to exist a very urgent need for timely consideration and constructive thought to be given to this subject.

The benefits of the Grid system have not as yet passed through to the consumers, both industrial and domestic, and one may ask where has been that co-ordination on the part of the Incorporated Municipal Electrical Association and the large company groups so necessary to give this subject of standardization of tariffs the constructive view to a solution of this important problem.

Does this lack of attention indicate a selfish interest on the part of an authority or company—that, although knowing that some time in the future the question of the standardization of tariffs will no doubt have to be considered, they prefer to do nothing practical in the matter until some other body is deputed to bring about standardization of charges, etc.? This would mean that the opinions of those most capable of forming them (through the usual progressive channels of committee meetings) would be to a great extent lost.

I cannot help feeling that now is the time for such efforts to be made, and the setting up in areas of a committee to explore completely the various tariff charges, and then set about grouping them under, perhaps, classes or grades, with a section for industrial works, small power users and shops, and business and household premises. With these three sections one could anticipate that comparisons of tariffs now charged could be reasonably discussed, with the result that some formula would be satisfactorily found to cover a standardized charge under the various grades and sections.

At the present time tariff agreements between supply undertakings and industrial users show many variations as to maximum-demand charges, power factor clauses (with or without rebate figures), and, in certain areas, one finds even large factories further controlled by an "on and off" peak clause.

It does seem that a further effort could be made to equalize maximum-demand charges, and to a great extent waive power-factor clauses, giving a final tariff truly beneficial to industry as a whole. "On and off" peak charges could no doubt be abolished.

One must emphasize here that were some formula evolved after discussions, one could believe that the Commissioners and Grid authorities would endeavour to co-operate in necessary adjustments of their charges to the various undertakings, realizing that such helpfulness would in turn further improve their operating efficiency.

In the case of small power users, business premises, shop lighting, hotels, etc., the existing variety of tariffs indicates that very considerable improvements could be made, and the lowering of charges would stimulate the uses of electricity generally amongst this class of consumer.

Lastly, the remaining class, the household consumer. The variety of methods adopted to bring about the so-called popular "two-part tariff" charge indicate in rather a conclusive manner many instances of unfairness when reviewing these methods. Surely some basis could be found which would lead to more equitable charges being levied.

The existing lighting, heating and cooking rates also illustrate the need for an effort to bring them more into line.

With the suggestion made for supply undertakings, both municipal and company, to get together in committee, say in areas first, and perhaps later in the form of a National Committee, so as to evolve a new basis for tariff charges for all sections, I feel that the results for the electrical industry as a whole would be truly beneficial and produce sure benefits for undertakings, manufacturers and users, and lead to an era of steady and progressive prosperity.

Returning to my main subject, I would direct your attention to the increasing complexity of the work of the electrical installation section of our industry. Owing to the ever-increasing size and diversity of the public demand for electrical energy, the installation engineer finds himself confronted by engineering and constructional problems of increasing complication. Large factories, huge departmental stores, theatres, and other places of major public assembly—even substantial blocks of residential flats—provide the electrical installation engineer with a considerable number of rather anxious problems in which internal distribution on metallic and non-metallic duct systems and by air-insulated bar distribution systems is playing an ever-growing part. In this matter I was rather gratified on a recent occasion to hear one of our prominent electricity-supply engineers confess that in modern systems of internal distribution he had "a great deal to learn from the electrical installation engineer"—that he found it extremely difficult to keep up-to-date in every direction—but on this matter I should like to pay tribute to many architects who are becoming increasingly electrically minded and are not so loath—as was the case only a few years ago—to make really adequate provision for transformer plant, rising mains and so forth, in their basic designs. In actual fact, of course, architectural design is rapidly assuming the dimensions of complicated engineering structure; and our leading architects—who, after all, are artists—are certainly to be congratulated on their general eagerness to meet the growing requirements of electrical installation and other public service engineers.

This growing complexity of electrical installation engineering serves to emphasize the need for some form of compulsory registration, to be applied both to electrical installation engineers and electrical operatives. Members of the public, who cannot be expected to differentiate between good work and bad, are entitled to be provided with some type of guarantee whereby installation practitioners, both employers and employees, can be held responsible for their work, and it is more than gratifying to note that this essential reform is receiving increased attention and support at the present day. This matter, however, is scarcely suitable for prolonged discussion in such an address as this; and beyond noting the suggestion that two types of registration certificates might be issued—one implying adequate proficiency in small domestic work and the other covering suitable experience of large-scale installation practice—

I must be content to remark that a National Committee has been hard at work on this subject for the past year or two and that really satisfactory progress has been made and is now being followed up with commendable energy.

It is to be noted that the growing complexity of electrical installation engineering is closely associated with constant endeavours to achieve its simplicity. In duct systems—and more so in air-insulated bar distribution systems—the fundamental purpose we have in mind is to achieve the greatest possible simplicity in carrying out subsequent extensions and in altering—often within the space of a few hours—the machine layout in large industrial plants.

Exactly the same desire to obtain simplicity is to be found, I think, in the Eleventh Edition of the I.E.E. Wiring Regulations, published within the past few months. I would remind you that prominent members of the electrical installation industry have played a large part in the deliberations of the Wiring Regulations Committee, and it is beyond question that the Eleventh Edition has achieved an extremely high standard both in the simplicity of its language and in the logical sequence of its provisions. In this matter at least two aspects of the Eleventh Edition are worthy of special notice, namely (*a*) the extremely valuable requirements now prescribed to secure some measure of installation examination and testing at regular intervals of time, and (*b*) the broadening of its requirements, and a wider recognition of the domestic diversity factor, in order to secure more "convenience" outlets with the use of rather less copper than has been demanded in the immediate past.

Since electrical installation engineers are in the closest possible touch with all classes of consumers, they are in an exceptionally favourable position to appreciate the very speculative condition into which so many of our earlier installations have degenerated. Tens of thousands of installations have been in service without inspection of any sort for 20 or 30 years. During this period the most singular alterations and extensions have been carried out by one person or another—frequently by amateurs and men of no special training whatever—and it is simply beyond question that the new re-testing and certifying clauses (Nos. 6 and 1108) have not appeared one moment too soon.

Where suitable diversity clearly prevails—as it does in the vast majority of our smaller domestic installations—it is equally valuable from a development point of view to be able to provide an increased number of outlets on the same sub-circuit—naturally enough under proper fuse protection—and I am one of those who believe that the principle will be the subject of even broader treatment in the future. An adequate, to the point of lavish, provision of socket-outlets lies at the very root of electro-domestic convenience, and I believe that one power circuit to an ordinary living-room is adequate enough to supply all the normal—and occasionally abnormal—requirements of such an apartment. Two 15-ampere socket-outlets in full use in one small room would very quickly raise the temperature of such an apartment to that of an oven: in other words such full use would scarcely ever be made, and the Regulations now recognize that fact in the clearest possible terms.

Before leaving the essential safety of electrical usage which our Wiring Regulations are designed to ensure, I feel that particular mention should be made of the stress placed by the Eleventh Edition on all-insulated equipment, as well as earthing exemptions in "earth-free situations"; and also of the revived interest that is now being displayed in lower voltages for certain domestic uses. Whether the whole domestic supply voltage should be lowered by a comparatively large house transformer to something rather less than half of the standard 230 volts, represents a very large problem indeed, but I feel that much is to be said in favour of very low-voltage supplies to bathrooms and so forth, for the operation of electric razors, shaving-water heaters and similar equipment.

Because the matter seems to excite such strongly opposing views, I hesitate to say very much concerning the round-pin *versus* flat-pin plug controversy. It is a singular fact, however, that while practically all our switchgear and so forth have been designed on flat-blade principles and have operated with complete success for many years, our socket-outlets have been standardized as round-pin accessories. The round-pin arrangement seems to have represented a direct departure from ordinary practice, and exactly why this was done is really unknown to me. On the other hand, I feel that the lack of effective fit and contact—the lack of interchangeability—between different makes of round-pin plugs and socket-outlets alleged to be standard, is due not so much to the hurry of mass production as to small manufacturing differences exhibited by one product as compared with another. That this is so appears to be proved by the fact that the mass-produced plugs of one manufacturer are reasonably satisfactory when used in his own mass-produced socket-outlets, although the plugs in question may fail in being either too tight or too loose when inserted in another make of socket-outlet. Such being the case, one is moved to wonder whether different makes of flat-pin accessories might not exhibit similar provoking deficiencies.

Turning to the immensely large field of electrical development it seems to be futile to select no more than one or two directions in which revolutionary progress is likely to be made. Electrical applications seem to be infinite in variety and capable of infinite expansion, and I feel that we have done little more than touch the fringe of such possibilities at the present day. Passing reference may well be made, however, to the revolutionary outlook brought into view by the electric discharge lamp. In this matter we have done little more than commence the use of fluorescent substances to modify the light quality of the lamp itself, while the use of fluorescence for decorative purposes, both in places of public assembly and in the home, has hardly been touched at all. There are, too, many striking possibilities of ultra-violet fluorescence for the location of switchgear, recording instruments and so on, under A.R.P. conditions, and also for the illumination of traffic signs and even traffic policemen under war-time blackout conditions. All these matters are very familiar to you, however, and I mention them simply as an indication of the immense development field that confronts us in every direction—lighting, heating and power.

In all that has gone before I feel that I have been able to say very little that is either novel or fresh to any one of you, and I am inclined to think that the initial task confronting me was, in this respect, beyond achievement. All said and done, the subjects that are really new are fit for technical communications to the *Journal* and not for Chairmen's Addresses. What I have attempted to do, however, has been to remind you of the essential importance of the work of the electrical installation industry and of the very great, nay fundamental, part the installation engineer plays in the steady progression of our industry. The fact is, of course, that the whole future welfare of the profession and industry depends absolutely on our ability to sell the electrical idea to members of the general public, and it is in performing this essential service that the electrical installation engineer is entitled to the supporting regard of all other sections of the industry. I have endeavoured to point out to you that the work of the electrical installation engineer is becoming increasingly complex, and it necessarily follows that arrangements must be made to attract the best possible men into the installation world and to render it worth while for them to stay there. The need is to ensure a reasonable degree of commercial stability for all qualified members of the installation industry and to provide a fair degree of remuneration for the services they render.

The whole position is admirably summed up in the concluding words of the introduction to the electrical industry's "Fair Trading Policy." It is pointed out that the main purpose of the policy is: "The regulation of business between all sections of the electrical industry, so as to ensure that the function of each is defined and understood, and that each receives the fair reward of his labour, to the end that equity and fair dealing prevail throughout the industry, that the public be well served, and the cause of electricity advanced."

MERSEY AND NORTH WALES (LIVERPOOL) CENTRE: CHAIRMAN'S ADDRESS

By W. HOLTTUM, M.Eng., Member.*

(*Address delivered at* LIVERPOOL *16th October*, 1939.)

"THE MENTALITY OF THE ENGINEER"

In choosing this subject for my Address it is not my purpose to deliver a discourse from the precept "Know thyself," which, while of general utility, suggests the habit of introspection, a diversion which it is far from being my wish to encourage unduly. At the same time the nature of the activities with which the mind of the engineer is normally occupied may make it of interest and use to give some consideration to his mental equipment.

It is not intended to imply that there is any very definite form of mentality suited to engineering to the exclusion of any considerable variations, and it may at once be admitted that the difference between the mentality of a business man in any walk of life and a writer, artist, scientist, or musician, is likely to be greater than the difference between an engineer and a business man. Moreover, in the higher reaches of the administrative scale the difference in mentality called for in different lines of business is a vanishing quantity. A penalty of the higher positions is a diminishing contact with the materials of commerce and a greater dependence on trained staff for presenting the results of technical work, in order to save the time and study which close personal contact involves.

In considering the mentality of the engineer it is not therefore with the general manager that we are concerned, for I submit that an efficient manager would with proper initiation have been practically equally efficient in any one of a dozen different directions. An interesting illustration is the recent transfer of a director-general of broadcasting to the chairmanship of an air-transport concern. We are rather concerned with the intermediate man who has some contact with the materials of commerce and at the same time has to take account of policy.

The mental quality most naturally to be attributed to the engineer is that of mechanical ingenuity or constructiveness. This is a peculiar gift, distinct from reasoning power though reinforceable by it, and might be described as the intuitive realization of the mechanical possibilities of the association of an assembly of parts. Constructiveness is to machines what reasoning power is to knowledge. Clearly the evolution of machines is dependent on this quality, and it plays no less a part in the conceptions of the superficially simpler but more imposing works of the civil engineer. Yet, unfortunately for its owners, the supply of it is generally in excess of the demand—witness the flood of inventions continuously poured into the Patent Office, only a small proportion of which comes to fruition. Seldom does a demand for a mechanism to fill some new need remain unsatisfied. If it does, it is likely to be some incidental problem involving another art or science which stands in the way.

So while constructiveness along with good average mentality will not make a great engineer, neither can it be regarded as an essential of even moderate success. On the other hand, it may be the corner-stone which will make an otherwise competent engineer supreme in his profession, and it was possessed superlatively by the great engineers of the past.

It may be questioned whether any of our contemporaries will 50 or 100 years hence stand out in history as do the well-known names of 50 to 100 years ago. While it would be rash to say that the basic discoveries and inventions have all been made, it will at any rate be admitted that they are now, and are likely to continue to be, much fewer and farther between, and outstanding ability is less likely to discover the road to lasting fame. This statement does not, however, take account of the possible engineering applications of the development of atomic physics.

I have seen engineering defined by an American writer as the art of the economic application of science to social purposes, a definition which perhaps errs on the side of being rather wide. It is to be noted that engineering is an art, a word most commonly used of the mediums of the creative expression of emotion such as music, painting, and literature, but in this context used in the lower sense of something which depends upon skill, natural or acquired, though in the stage of development now reached mechanical constructiveness plays a diminishing part in the skill which has to be personally exercised by the responsible engineer.

It is interesting to consider whether there are any lines of mental attainment which have no application in engineering; and one immediately thinks of the arts referred to above. The type of mind which is drawn to engineering tends to be one to which the arts make a limited appeal, as is to be expected in a profession where they certainly have limited scope. Facility in the use of language is the exception to this, and is of value in all walks of life, but while those of more artistic disposition may be acutely conscious of the music of words, the engineer is likely to value them little apart from their purpose. Yet it is interesting to note that the instincts of the engineer by no means preclude the artistic temperament. Faraday and Kelvin were lovers of music, and the former of pictorial art also. Ferranti,

* British Insulated Cables, Ltd.

whom I suggest may be regarded as supremely an engineer and by good fortune arrived when the stage was set for the exercise of his remarkable powers, is an interesting case in that with strong artistic tendencies in both parents, which came out also in his half brothers and half sisters, he apparently showed little if any leaning in that direction, but the strong instinct of idealism which inspired him was directed ever to the development and greater perfecting of mechanical construction.

It is perhaps doubtful whether religious tendencies may be included under the heading of mentality, yet it is of interest to note that these three were all sincerely religious men. Of Faraday, Tyndall wrote "He believed the human heart to be swayed by a power to which science and logic opened no approach, and, right or wrong, this faith, held in perfect tolerance of the faiths of others, strengthened and beautified his life." And Faraday himself said "I do not think it at all necessary to tie the study of the natural sciences and religion together, and, in my intercourse with my fellow creatures, that which is religious and that which is philosophical have ever been two distinct things." Much has been written since on the relation between science and religion, but it remains, alas, that intellectual and moral progress display a lamentable independence of each other, so much so that our profession, which has been developed in meeting the legitimate needs of mankind, is in danger of being used in accomplishing its destruction.

It may also be beyond our scope to consider the bearing of the Christian virtues on the efficiency of the engineer, but it is an interesting speculation as to how much is lost both to the individual and to the industry through the generally assumed unacceptableness of personal criticism.

The advance of engineering and allied sciences during the present century has resulted in an accumulation of experience such that its co-ordination for the guidance of further work has become a very serious problem. As Lord Stamp said in the Rankine Lecture at Liverpool University last year, "the problem of satisfactory indexing for scientific knowledge as a whole has not yet been solved." And it might be added that the probability of solving it would seem, from the nature of the case, to be somewhat remote. And to further quote Lord Stamp "The technique of the mastery of masses of data, so that the essentials are always present, and so that supporting data at any point which may be the focus of interest are always available at call, is partly machinery, but machinery that requires informed guidance at every stage." This suggests the problem of the correct relation between individual knowledge and records, and while the most useful kind of knowledge is to know how to find out anything that may be required, yet there must be some retention of the knowledge obtained in order to make use of it and to relate it to the situation in hand. Related knowledge is both the most useful and the most easily retained, and while the mechanical use of records will enable the most complicated work to be repeated, the accumulation of knowledge within one mind is obviously essential to new development, and for this there must be memory. The orderly mind will so absorb ideas and information that each intake falls automatically into its place, and so helps to build the complete mental structure, instead of roaming about until it gets lost. Memory is a faculty which will compensate for many deficiencies, for if the mind can but retain a sufficient variety of illustrations, something will be found to give guidance in almost any situation. But a mind thus guided by memory with little original thought is essentially conservative, a quality at any rate more reliable than mistaken judgment from faulty reasoning or insufficient knowledge. So memory alone, combined with very moderate other qualities, will go a long way in professional success, but is only the starting point for original work.

Between the uses of records and memory lies the advantage of reference to another brain having information responsively available from any angle, and the highest efficiency of the individual is usually associated with such co-operation. While no two people can see any situation identically, the contributions of other individuals may yield something of value unobtainable in any other way.

The efficient engineer requires by some means to take account of available experience, and to this end it frequently happens that the right approach to a problem is of more importance than previous knowledge, which must almost inevitably be incomplete. Herein, perhaps, lies a main difference between the man who, while quite competent at his work, is unlikely to rise much further, and the one whose progress is limited only by his opportunities. While it seems probable that the capacity of the human mind is unlimited, the extent of possible knowledge is so far beyond the scope of any one mind on account of lack of means or opportunity to gather it, that any action taken by an individual is unlikely to take account of all relevant matters, and so may be—or is even likely to be—to some extent miscalculated. I suggest that the escape from this somewhat depressing conclusion lies in the importance of personality, in the expression of which the chief value of any action lies, and which may be so exercised as to allow for possibilities in regard to which evidence is not brought to bear. It may seem rather far-fetched to suggest any general application of such an idea, in that in engineering work the results of action remain long after the personalities responsible have vanished from the scene, and I think the bearing lies rather in personal dealings and individual works.

The independent unit principle which makes possible many complicated mechanisms, such as the motor car, has some application mentally. On a car, each part can be detached and dealt with separately and in most cases is assumed to have no bearing upon the other parts. It is difficult to see how an alteration in design of the back axle could affect the windscreen wiper, though it would be rash to assume a design of car was not possible where they would be interdependent. Similarly, certain branches of knowledge have an assumed independence of others, but the essential unity of the realm of ideas and the superficial exploration of it by the human mind leave the possibility of undreamed of associations and connections.

In considering the mentality which best goes to make an engineer, I would first make the obvious statement

that training counts for far more than natural abilities. In fact I would say that there is no more reliable and admirable servant of a company than one who by application qualifies for a job for which he has little natural aptitude.

The qualities which with training and application go to make a competent engineer are not easily defined. First, perhaps, is the ability accurately to assess needs and means in regard to engineering matters, and to take account of all the relevant factors in equating the one to the other. And if to that is added personality, the capacity for fitting into the human organization and impelling it by an individual contribution, then we should have a fairly complete engineer. But a statement of such composite qualities is perhaps of little use, and their analysis is not easy, for they may be composed in various ways. The less complex qualities of industry, perseverance, idealism, judgment, memory, and willingness to take responsibility, find scope in all occupations. The engineer is one who is impelled to employ these qualities in a particular direction. And this impulsion in most cases comes from the instinct of mechanical constructiveness which, I believe, is possessed by the large majority of engineers, not because each finds scope for it in his particular line, but because it was the cause of the choice of profession which he has made. And having made the choice, in many cases the capacity may fall into disuse (though retaining some directive value) owing to the many ramifications which limit the association of the engineer with the material expression of his work. In making decisions, however, all mental powers are called into play, particularly as it is frequently necessary to act on evidence less complete than would be desired. Then comes the opportunity for judgment, which must balance the probability of success against the possible consequences of failure. And here is a point at which progress and prestige are sometimes at variance, for it may require an unusual devotion to be willing to give progress its opportunity at the risk of personal failure. Where the paramount need is safety a clear choice is frequently indicated, but there are occasions where the only scope for effective experiment, to be carried out with proper agreement and safeguards, is in the execution of an order. Again, where there are alternatives which offer equal promise, there is a tendency to choose the most orthodox, as untoward results are then likely to produce a less unpleasant reaction. There are cases, however, where the engineer may be fortified by the reflection that even if his decision does not work out well, it will at any rate be impossible to prove that there was any better way.

The engineering temperament, if such there be, is distinct from the scientific, and the engineer in general is perhaps rather disinclined to abstract reasoning and the scientific method, and is possessed by impatience to "get on with the job." Everyone knows the student who shows little taste for or success in studies and yet makes a quite successful engineer. He is usually a personality of some force and persuasiveness, with a keen eye to essentials which, in his view, need not include the passing of examinations, and an appreciation of the value of a talking acquaintance with things. The desuetude into which most book-learning usually falls, and the eventual ascendance of the personal factor over the technical, prevent one from regarding such successes as fortuitous or unmerited. Usually there are limits to the progress achieved in such cases, but it would be unsafe to dogmatize. Studiousness, or the intellectual type of mind, is largely independent of force of personality, and may not be coupled with originality or initiative, and so alone is apt to command but a modest reward. Yet, lest these remarks be misconstrued, I add the obvious assertion that a mind which lets pass the opportunity for technical training is unlikely to find it recur, and has missed something of irreplaceable value.

In ascending the scale of responsibility the ascendancy above referred to of the personal factor over the technical becomes more marked. Incidentally, it might be considered that for an engineer the ratio between the two should fall within certain limits. Yet it is to be noted that the organized training of the engineer is devoted entirely to the technique of engineering and not at all to the technique of personal dealings; and there are I suggest two reasons why it is appropriate that this should be so. There is already more than enough technical material to fill the university curriculum, and this after all must claim first place; and secondly the desirable personal qualities are closely related to those produced by right upbringing and environment, and the assiduous employee who has latent capacity for higher responsibility will himself achieve the right combination of technical and personal qualifications. This is not of course to decry study of the art of administration so far as the individual has opportunity.

Everybody would like to know a sure recipe for becoming eminent in his profession. What is it that has to be added to the obviously indispensable qualities of the good average individual? I hazard the guess that it is a memory approximating to perfect and an efficient subconscious mind, which two are no doubt not unrelated. The too conscious pursuit of all the necessary mental development involves too great a strain. The efficient mind should become largely automatic; conscious mental operations being devoted more and more to wider aspects. Such a way encourages originality, a quality seldom found and difficult to define. It is hard to say how far the difference is one of degree or of kind between the active mind which works by the combination in various ways of absorbed knowledge, and the one which brings into the combination self-produced conceptions which can give progress new life and direction. While it is said that there is nothing new under the sun, and it is evident that knowledge grows by fresh associations of existing ideas, combined with experimental discoveries, yet there seems to be a type of mind quicker to perceive the possibilities of such fresh associations, and such perception I suggest most effectively takes place in the subconscious. Originality is surely a constituent of genius, which Edison defined as 1 % inspiration and 99 % perspiration, evidently assuming the inspiration to be of very high order. The perspiration implies an assiduous and thorough attention to detail; and as this usually results in attention to some amount of unnecessary detail, it follows that for the highest efficiency there are some details that must be allowed to pass, as the time can be better used in other ways.

The foregoing suggests a reference to the type of mind most suited to research, which does not quite come within my subject. Research is the province of the scientist rather than the engineer, but the research engineer stands between the two and has an indispensable function. It is difficult for the pure scientist to maintain adequate contact with practical applications, and the research engineer provides or should provide the necessary link. He requires to have the mind of a technically trained engineer but with his enthusiasm directed rather to perfection than to spectacular accomplishment, and with an independent and enquiring outlook. The commercial aspect should be kept in the background, but without being ignored. A knowledge of mathematics is essential; but while this subject is at the base of engineering, the highly mathematical mind is rather too fond of abstractions to have force in practical work, and while such skill finds frequent useful applications it is a tool which, apart from the research worker, can in many cases be effectively wielded by deputy.

It will not be overlooked that the engineer's primary incentive is, alas, to earn his living, although the choice of occupation is often made without knowledge of its economic possibilities. The engineer also likes to think of himself as a benefactor to the community, albeit an involuntary one, and I think he can have the satisfaction of feeling that these two aims run together in his profession with a fair degree of harmony. It rests with the community as to whether the freedom and leisure conferred by his activities are put to advantageous use.

My remarks have been directed mainly to the actual rather than to the ideal. They might be considerably extended by describing the attributes of the complete and perfect engineer, and the subject remains for anyone disposed to give it more comprehensive treatment.

NORTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By W. DUNDAS, Member.*

"DEVELOPMENT OF ELECTRICITY SUPPLY"

(*Address delivered at* LEEDS 21*st October*, 1939.)

Looking back on the days which many can remember, when the supply was confined to relatively few premises for lighting, with a sprinkling of small motive power here and there, and when the tramway load provided the major output from the station, little did we dream then of the achievements that exist to-day, when the service, made possible by the rapid march of progress in all branches of the industry, has become a vital necessity in the life of the nation.

The question of saturation has given rise to much conjecture for many years past, when it was thought that the load could not be expected to maintain the same rate of growth much longer, but a glance at the curves in Fig. 1 does not give that impression even to-day, and it is somewhat difficult to say when the curves will begin to show signs of flattening out, judging by the slope. The continued upward trend of development is very encouraging to those engaged in the industry, and in that connection it will be of interest to make comparisons with developments in other countries.

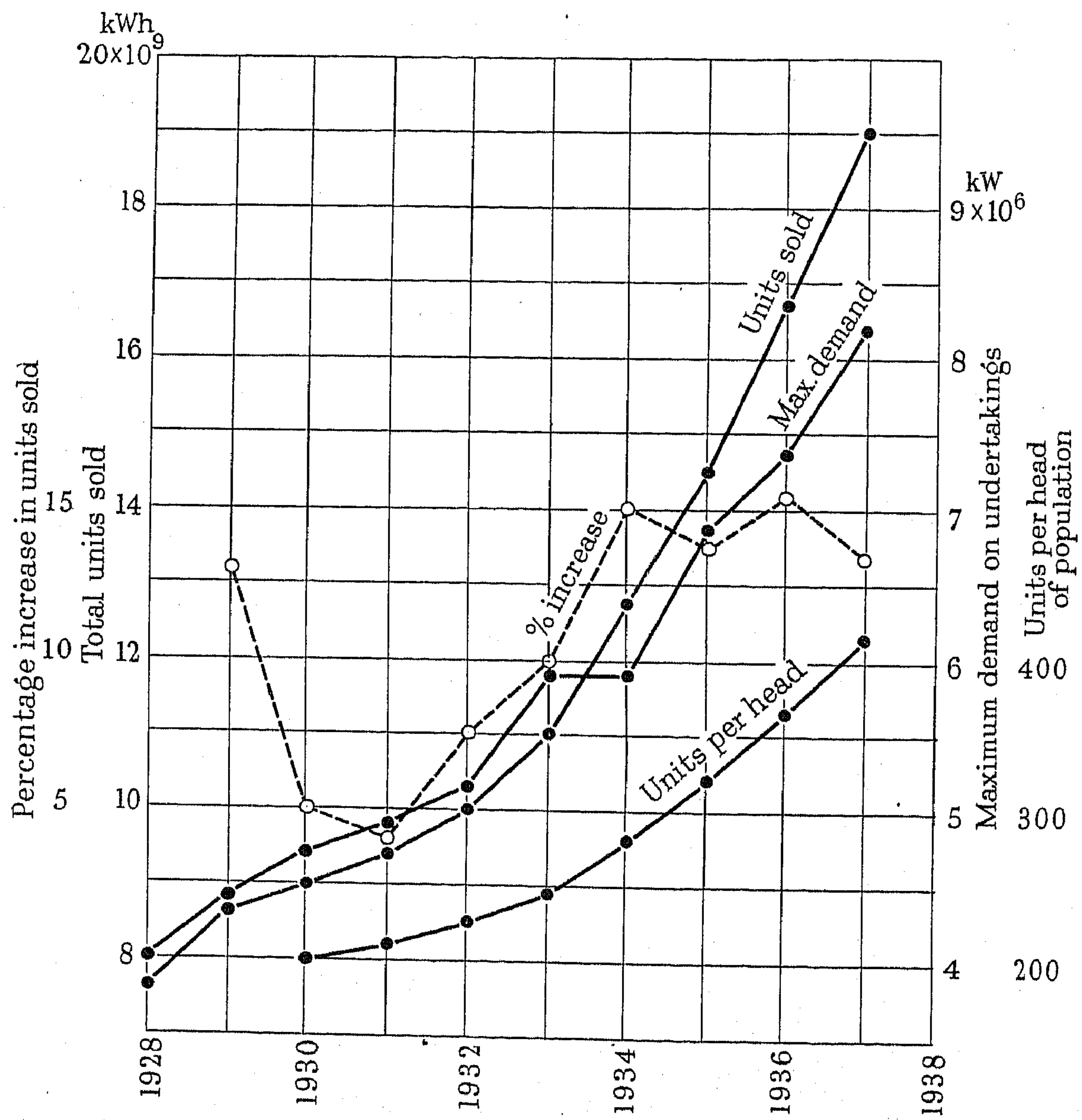

Fig. 1

The rate of development in this country is indicated by the curves in Fig. 1, which have been plotted from the statistics published by the Electricity Commissioners in their Annual Reports. These show the units sold by undertakings in Great Britain, excluding Northern

* City of Bradford Electricity Department.

Ireland, for the past 9 years, together with the percentage increase in each succeeding year, the consumption per head of population, and the undertakings' maximum demands. The effect of the industrial depression on the rate of rise in the years 1930–32 is most marked, but it is significant to note that an increase was maintained due to the development of the domestic load. The rate of increase in the units sold has remained fairly constant during the past 4 years, and, whilst recent restrictions are likely to have an adverse effect in certain directions, that, no doubt, will be more than counterbalanced in others.

Table 1

No.	Country	Year	kWh from Public supply	kWh from Private industrial plants	Total kWh per head of population
1	Norway	1936	984	1 670	2 654
2	Canada	1936	—	—	1 910
3	Switzerland	1937	724	398	1 122
4	Sweden	1937	758	361	1 119
5	U.S.A.	1937	787	201	988
6	Finland	1937	—	—	688
7	Germany	1937	383	270	653
8	Belgium	1937	298	332	630
9	New Zealand	1937	615	6	621
10	Great Britain	1937	414	174	588
11	France	1937	278	113	391
12	Czecho-Slovakia	1937	109	175	284

The results shown in Fig. 1 do not take into account the output from industrial plants, which adds considerably to the total, details of which are given in the form of an Appendix to the Electricity Commissioners' 18th Annual Report, from a census of production for the years 1930 and 1935 of the various industries in Great Britain, excluding small firms employing not more than 10 persons on an average; also private plants in commercial establishments, hotels, hospitals, etc., many of which met their requirements either wholly or in part from their own generating plant.

There was a considerable increase in industrial requirements during the period under review, both in the direction of private generation and purchased energy, and the latter has now assumed priority. Private generation is—as would be expected—mainly associated with industries requiring process steam, such as paper, chemical, and textile trades.

Mr. Lamb, in his Presidential Address at the I.M.E.A. Annual Convention this year, gave an interesting Table showing the utilization of electricity in various countries. This, with his permission, is reproduced here as Table 1.

From those figures it will be seen that Great Britain is a long way behind with respect to the consumption *per capita*, but in making comparisons with the achievements in other countries it is necessary to bear in mind conditions characteristic of those countries, such as natural hydro-electric resources, the effect of preponderating industries, electrification of railways, export of electrical energy, and absence of fuel, all of which have an important bearing on the degree of electrification attained. The position in Great Britain is totally different, being dependent almost wholly on steam for the production of electrical energy. Here we have no preponderating industries such as in Canada, Scandinavia, etc., or extensive railway electrification (as in Switzerland) utilizing hydro-electric resources, and in order to obtain a comparison under similar conditions reference again is made to Mr. Lamb's paper, in which he made a comparison of the public supply development between London and New York and the area served by the Detroit Edison Co. in Michigan. The figures are given in Table 2, to which those for the County of Yorkshire have been added.

Table 2

Year	1936–37	1937	1936–37	1937	1936–37
Territory	Greater London	Greater New York	Lancashire	Detroit	Yorkshire
Area (sq. miles)	693	700	1 867	7 587	5 818
Population	8 202 000	8 000 000	4 928 000	2 555 262	4 390 000
Consumers:—					
Average over the year	1 827 694	2 337 907	905 250	623 629	913 876
Units sold:—					
Total (millions)	4 022·6	5 605·3	2 288·1	2 718·9	2 014·6
Per consumer	2 201	2 398	2 528	4 360	2 204
Per head of population:—					
Domestic and commercial	238	313	152	418	146
Industrial	153	233	270	593	278
Street lighting	11	18	8	25	5
Traction	88	111	34	28	30
Miscellaneous	—	26	—	—	—
Total	490	701	464	1 064	459

It will be seen from Table 2 that the areas and populations of London and New York are approximately equal, and there is not a great difference in the consumption per consumer, but New York has a greater number of consumers and also a higher consumption *per capita*. Comparing developments in the Counties of Lancashire and Yorkshire with the area served by the Detroit Edison Co., America again shows a greater use of the supply, both in industry and in the home.

From the latest returns available, the units sold for industrial purposes in the Detroit area amount to over 76 % of the total sales, the consumption taken by large power users representing over 55 %, with an average consumption of over 3 million units per annum. The domestic consumption accounts for close on 17½ % of the total. The average domestic consumption was 891 units per annum and for farms 835, the former showing an increase of 11 % over the previous year.

The industrial consumption in America is much greater than in this country, and especially purchased energy, which is rather significant seeing that the position is not affected by particularly low tariffs or the absence of competitive forms of energy; oil, for example, being very much cheaper than in this country. The reason for that may be associated with the tendency in the States towards the more rapid obsolescence of plant and readiness to adopt improvements, and with the possibility of being able to turn capital invested in private plants into more profitable account in their own industry, and to concentrate thereon, leaving the question of power supplies in the hands of the supply authorities.

Another very remarkable feature is the high load factor obtained in the States, which has reached a figure of 57·8 % among the utilities dealing with an annual sale of 100 million units and over, and is undoubtedly due to long-hour industrial working.

In consequence of the severity of the winter in America, central heating has been adopted in houses, offices, hotels, stores, etc., where the temperature maintained is considerably in excess of that usually found in this country, and under those conditions it is not surprising to find that electric heating is not competitive with other sources of heat, such as oil, natural gas, or steam, the last mentioned being supplied from central heating stations in some of the large cities. This fact will have an influence on the load factor, and the supply authorities have not to face the effects of exceptional peaks such as were experienced in this country last December.

It is generally understood that the size of an undertaking is a measure of the possible success in developing the supply, and, whilst that is true in the case of a number of the smaller concerns, it does not always apply, as will be seen from the figures in Table 3 which has been compiled from statistics published in the *Electrical Times* Supplement. The figures show a considerable variation in the maximum demand and units sold, the former averaging 0·165 kW for all groups. It is not possible to compare relative load densities or distribution costs, owing to the diversity in the areas served by the various undertakings, and densities per square mile vary from less than 30 kW to 33 000 kW in

Table 3

ANALYSIS OF UNDERTAKINGS

Group	No. in group	Population (thousands)	Average No. of consumers	Average maximum demand: Total average	Average maximum demand: Per head	Average maximum demand: Per consumer	Average units sold: Total average (thousands)	Average units sold: Per head	Average units sold: Per consumer	Average units sold: Industrial	Average units sold: Lighting and domestic	Average units sold: Miscellaneous	Load factor	Saturation	Average selling price per unit	Range of selling price per unit
													%	%	d.	d.
1	4	Over 850	196 660	195 210	0·194	0·993	560 417	558	2 850	56·3	31·85	11·85	32·75	66·4	0·905	0·77/1·0
2	4	450/550	125 150	104 150	0·211	0·83	321 430	650	2 660	54·5	32·5	13·0	35·2	76·8	0·833	0·63/1·01
3	4	300/450	83 000	49 320	0·139	0·594	135 819	382	1 636	52·2	46·3	1·4	31·4	83·3	1·0	0·89/1·45
4	6	250/300	64 200	43 400	0·155	0·676	122 920	437	1 913	51·3	39·0	9·7	32·4	78·5	1·013	0·93/1·16
5	13	200/250	52 000	37 100	0·171	0·713	102 600	473	1 970	58·8	39·4	1·8	31·6	91·4	0·978	0·73/1·25
6	8	160/200	41 480	43 980	0·251	1·06	131 535	751	3 170	35·2	28·7	36·0	32·74	78·0	0·856	0·66/1·21
7	12	135/160	33 940	22 780	0·160	0·670	65 680	467	1 935	48·8	44·1	7·06	32·93	84·6	0·955	0·70/1·77
8	8	110/135	29 650	17 310	0·138	0·584	53 500	425	1 805	49·8	37·47	13·6	31·5	87·1	0·955	0·64/1·56
9	12	95/110	22 300	13 640	0·133	0·612	37 300	364	1 672	47·0	44·5	8·5	31·8	80·2	1·133	0·93/1·82
10	11	70/95	19 770	14 140	0·168	0·715	39 030	463	1 975	44·2	43·7	13·1	31·5	73·9	1·053	0·76/1·56
11	22	50/70	15 300	10 430	0·164	0·682	29 900	469	1 955	49·5	42·2	8·3	32·5	80·2	0·979	0·59/1·86
12	9	40/50	11 860	5 086	0·103	0·429	12 700	259	1 070	30·1	55·1	14·8	28·5	59·3	1·464	1·18/2·27
13	13	20/30	5 630	2 840	0·126	0·503	7 220	321	1 280	35·6	56·0	8·4	29·0	80·9	1·19	0·6/2·75

the case of the thickly-populated area of St. Marylebone, where the maximum demand per head exceeds 0·8 kW. The units sold per head also vary considerably, and in a number of cases examined were influenced by the proportion of industrial load, which is not evident from the average figures in the Table except in the case of Group 6, where the bulk of the load under the heading of "Miscellaneous" appears to be industrial. Lighting and domestic loads predominate in the case of the small undertakings, and the position becomes reversed in Groups 1 to 6.

Where the selling price is high, development is retarded, which is only to be expected and is due to such factors as sparsely-populated districts involving high distribution costs, limited incomes of the majority of the population served, and special local conditions such as obtain in mining districts, where coal is available at a low price and where one fire serves all heating and cooking requirements.

The column referring to percentage saturation is the ratio of the number of consumers to the total number of premises within the area of supply, and provides an indication of development as far as consumers' saturation is concerned. In certain undertakings the figure exceeds 100 %, owing to the prevalence of flats, and a more accurate method would be on a basis of the number of actual to possible consumers, which could only attain 100 % if all premises were within service distance of the supply mains, a condition which does not obtain in many undertakings.

The average selling price and range of prices shown in the last two columns indicate attractive tariffs offered by some of the smaller undertakings, but there is a greater divergence than in the case of the larger undertakings.

INDUSTRIAL LOAD

Reference has been made to the increase maintained in this country in the direction of the power load, which continues to absorb the major output; also to the growing tendency towards purchased energy. This is noteworthy in view of the keen competition, especially in the heavy industries, with the Diesel engine and efficient and compact turbine units operating at relatively low steam pressures and temperatures, which with the type of steam-raising plant usually employed in factories and the general conditions of operation, together with the assistance of de-rating, enable low production costs for power and factory heating to be obtained.

The tariff offered for industrial load must be low to be competitive, but it permits a higher price than could be obtained by private generation on account of the saving in capital expenditure the consumer is called upon to bear, which becomes available for investment in his business, together with other advantages afforded by an outside supply, which are less readily capable of being expressed in terms of £ s. d. to a prospective consumer. The price obtained should prove remunerative to the supply authorities and not be subsidized at the expense of other classes of load, thereby retarding their development; but judging by the results obtained and progress made it would appear that those conditions have been satisfied, although some writers on the subject do not concur with that view.

The question of reliability of supply in time of war is of utmost importance, and may result in a revision of ideas with regard to important factories and institutions being self-supporting, or, alternatively, by affording duplicate supplies at divergent points of entry into such premises. It is quite conceivable that interruptions will occur as a result of aerial warfare, but it is not anticipated they will be of long duration where facilities exist, as they do in many places, for maintaining supplies by an alternative route.

According to a recent census of industrial power requirements in Great Britain, there is a considerable field for development of the power supply, and there can be no doubt that electricity will play an important role in restoring prosperity to the nation, as it does in the production of the necessities for war. There appears, therefore, to be every reason for an optimistic outlook in the future development of industrial power, resulting in an increased consumption *per capita*, which, according to the returns for 1937–38, amounted to 227 units.

TRACTION

The electrification of railways proceeds slowly, owing in some measure to the unfavourable financial position the railways are in to-day. The potential possibilities of the Diesel-electric locomotive, particularly for main-line operation, are likely to exert an influence on the choice of system to be ultimately adopted. This, however, introduces an important factor, namely that of utilizing national coal resources in preference to imported fuel, and this rather indicates a possible reason for delay in deciding the issue.

During the past two decades the electrified route mileage in this country has increased from about 350 to close on 1 000, and at present represents approximately 5 % of the total mileage of railways. The developments have been mostly centred in and about London, where the frequency of service and increased schedule speeds required to deal with the volume of traffic have been made possible only by electrification.

The advantages obtained by the change-over from steam to electricity depend largely on the factors indicated above, together with other local conditions such as steep gradients and tunnels. Regenerative braking permits of higher speeds on down grades, whereas, with mechanical braking, speed is limited on account of overheating of brake shoes and wheels.

While certain economies are effected by lower power costs, the major economies lie in the direction of wages costs, which, according to a report, have effected a saving of over 50 % by the more efficient operation of electric trains. Maintenance costs have shown even a greater saving.

Turning to road transport, the advantages afforded by internal-combustion engine-propelled vehicles have had an adverse effect on tramway undertakings, and the increased volume of traffic now carried on the roads has resulted in serious congestion, especially in towns and cities. That, combined with the increase in speed demanded nowadays, has led to the abandonment of trams in many places, and during the past few years the number of trams in service has been reduced by close on 40 %, whilst the route mileage has fallen by

over 60 %. It does not necessarily follow that trams will entirely disappear, and they are being retained by a number of the larger transport undertakings, where no doubt they will be as much appreciated during the present period of black-out as they are during foggy weather.

The substitution of trolleybuses on tram routes continues to make progress, and records show that approximately half the number of trams so far scrapped have been replaced by that type of vehicle, serving about one-third of the displaced tram route mileage. The trolleybus has proved a popular type of road service vehicle and eminently suitable for dealing with heavy traffic routes, possessing the highest accelerating power of any road vehicle of its class, enabling it to attain a speed of 30 m.p.h. in less than so many seconds. The City of Bradford can lay claim to be among the first, if not the first, in the field in this country to adopt the trolleybus, under the direction of the late Mr. C. J. Spencer, then engineer and manager of the City Tramway Department, who introduced a service of single-deck vehicles over a route length of $1\frac{1}{4}$ miles in June, 1911. To-day there are in Bradford 135 trolleybuses, which have superseded trams on a number of routes totalling 35 miles.

A good deal of controversy exists between the protagonists of the trolleybus and the Diesel-engined vehicle, and by all accounts there appears to be little to choose between the running costs of the two, and whether other factors, such as interest and depreciation on vehicles and overhead equipment, together with its maintenance costs, will turn the scale in favour of one or other will depend on the service requirements.

DOMESTIC LOAD

It is estimated that 85 % of the total number of consumers of electricity belong to the domestic class. However satisfactory that may appear from one point of view, the same cannot be said from the standpoint of use made of the service when it is realized that the average consumption per consumer only amounts to 600 units per annum, and in the case of a number of undertakings is very considerably less. Table 4, obtained from an analysis of the domestic consumers in the City of Bradford, illustrates that fact, and appears to be typical of most industrial towns and cities in this country.

Table 4

Rateable value	Number of houses		Number of houses on supply		Approximate average annual consumption per consumer
	Total	%	Total	%	
Not exceeding £10	47 918	54·5	23 887	49·8	500
Between £10 and £20	33 635	38·3	31 260	92·9	560
Between £20 and £30	4 558	5·2	3 874	85·0	1 170
Between £30 and £40	964	1·1	705	73·1	1 830
Above £40	877	1·0	628	71·6	3 030
					Average 616
Farms	—		106		
Flats	—		170		

The consumers' saturation is 69 %, the bulk of the consumers (91 %) occupying the smaller houses, where the annual consumption is low. It is somewhat surprising to find a lower percentage of consumers in the larger houses, but this may be explained by the fact that a number of those houses are vacant or have been converted into flats.

In order to obtain a quantitative idea of the consumption that might be expected, tests were carried out in a house of £30 rateable value equipped with electric water heating, cooking, radiators for occasional use, and miscellaneous small domestic appliances. Coal fires were used in the living room and kitchen during the winter months, a condition likely to apply generally owing to the desire of the people in this country for the open fire, which, incidentally, has an advantage from the supply authorities' standpoint by keeping down the maximum demand in the winter months and providing additional load during the summer months. Three graphs from the recording wattmeter inserted in the main supply to the house are shown in Figs. 2–4; these indicate the extent of the diversity of the load during three days in the same week under the conditions outlined above. The maximum demand over the week-day 4–5 p.m. peak averages round about $1\frac{3}{4}$ kW on the half-hour basis, but may occasionally be considerably increased, as shown on one of the graphs. The breakfast peak is slightly greater and more irregular in shape, and that that time of breakfast is fairly common in a number of households is shown by the marked peak at that period on the station load curve. The same conditions apply to the Sunday midday cooking load, which from observations made required 3 kW for half-an-hour plus 2 kW for $1\frac{1}{2}$ hours.

The total annual consumptions for the various services were as follows:—

	Annual consumption	Load factor
Cooking	1 792 units	5·15
Water heating	1 394 ,,	5·3
Radiators	897 ,,	3·4
Lighting and miscellaneous	569 ,,	10·8
Total	4 652 units	8·86

The capacity of equipment installed was 20 kW and the maximum demand over a half-hour period 6 kW,

which gives a load factor of 8·85 %, and 30·3 % on the station peak, corresponding to a diversity of 3·42, which would be somewhat greater for a number of similar houses taken collectively. The cost on the two-part tariff, consisting of a fixed charge of 15 % on the rateable value, 20 units per £ of rateable value, and the remainder at one-third of a penny per unit, works out at 0·651d. per unit. That is equivalent to a fixed charge on the maximum demand of £2 18s. 8d. at a unit charge of $\frac{1}{2}$d., and equating that to a maximum-demand charge of £9 per kW, the diversity for such consumers would have to be 18·4, which may be possible.

It is estimated, from further observations made with the elimination of coal fires, that the annual consumption would be increased at least threefold, with a maximum demand of 10 kW and 6 kW over the station peak, giving an annual load factor of 16 % (the load factor on water heating and radiators would approximate 14 %). The diversity factor would be considerably reduced owing to the nature of the heating load, which would increase the cost of supply, and it is very doubtful whether energy could be supplied on a large scale for heating purposes at an economical figure to compete with solid fuel.

An example of the possible annual consumption in the smaller houses is shown from records obtained

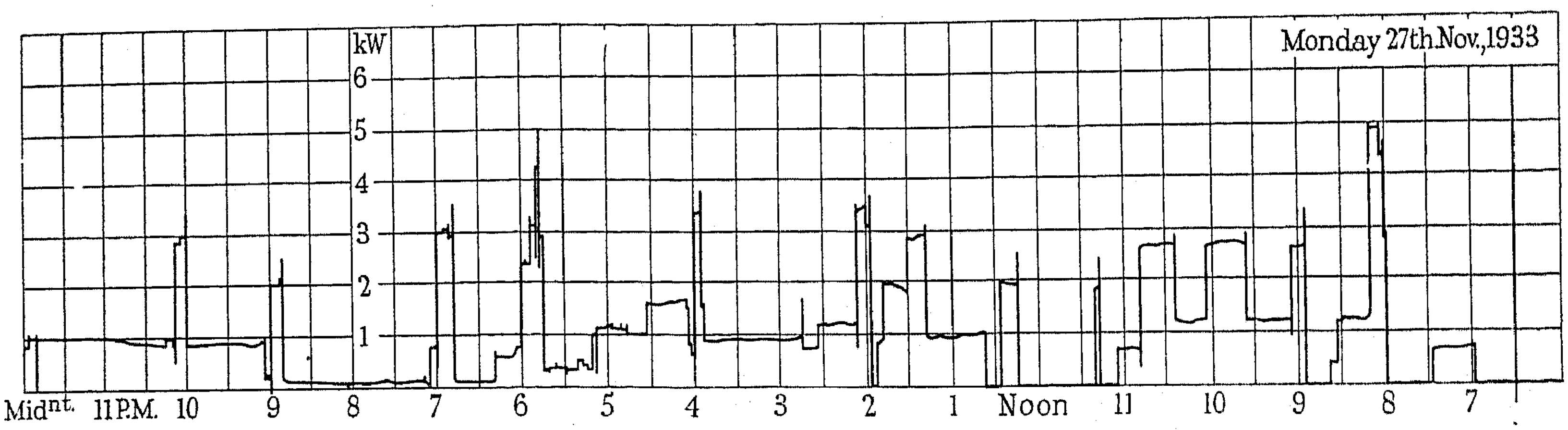

Fig. 2

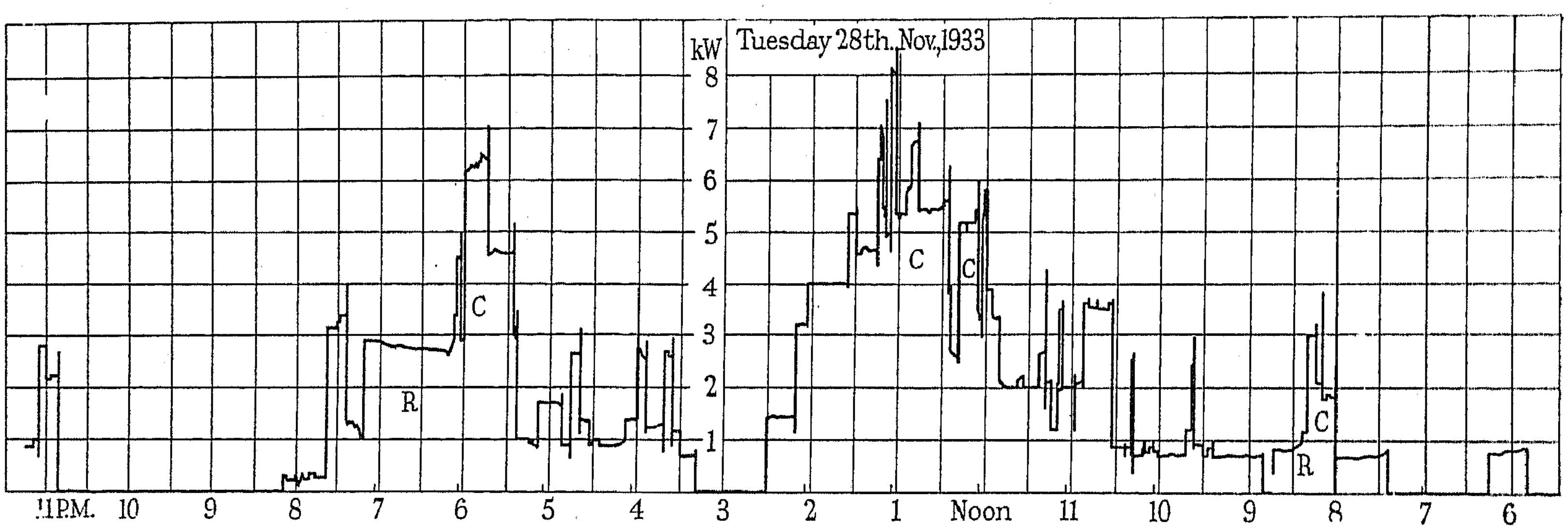

Fig. 3

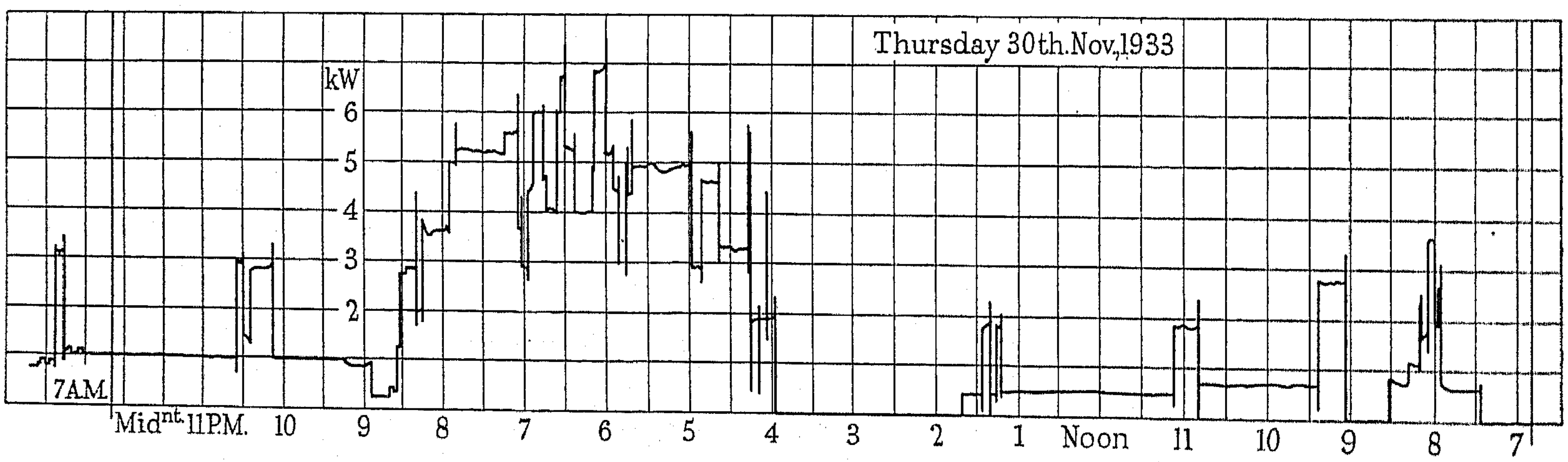

Fig. 4

from an estate containing 300 houses with an average assessment of £11 per annum, each equipped with one coal-fired range fitted with an oven and boiler for the hot-water supply, together with domestic electric appliances, including cooker, kettle, and wash-boiler, totalling 10 kW capacity. The maximum demand recorded was 152 kW, which occurred just before noon, and 83 kW at the time of the station peak, corresponding to a maximum demand per consumer of 0·502 kW and 0·277 kW at the respective hours. The average annual consumption per house was 1 360 units, and the price obtained 0·733d. a unit on a tariff similar to that previously quoted. The load factor was 30·6 %. It was not possible to ascertain the actual diversity of the load, but on the total installed capacity it works out at 19·7 and 36·2 at the times of maximum demand and station peak respectively, which is much higher than that obtained in the case of the £30 house, namely 3·34 and 11·4 where greater use was made of the service.

A comparison of the foregoing examples with the low annual consumption of the average domestic consumer clearly indicates the extent of the possibilities that lie ahead, which are further exemplified from statistics showing the relatively small percentage of homes possessing the necessary domestic appliances to enable advantage to be taken of the service beyond a very limited extent. The first cost of domestic appliances has in the past had a deterrent influence, but that has been largely overcome by the facilities for deferred payments afforded by the Electricity Commissioners for hire and hire-purchase of equipment. Also, assisted wiring out of loans is of particular assistance to people of limited means, where the service means much to the housewife, who from necessity is called upon to undertake the household duties single-handed. Similar facilities in the form of a grant-in-aid were introduced some time ago in the Province of Ontario, and it is of interest to note the advantage taken by consumers of purchasing domestic equipment, particulars of which are shown in the following figures reproduced from the Ontario Commission's 38th Annual Report:—

Appliance	Per cent saturation
Irons	74·9
Radio	72·2
Washers	45·5
Toasters	57·1
Hot-plates	16·9
Cookers	28·6
Water heaters	18·6
Vacuum cleaners	30·6
Radiators	7·3
Air heaters	29·6
Refrigerators	15·6

This list covers appliances in homes in the rural areas and may or may not be representative of the whole of the domestic consumers on the supply. The figures indicate the popularity of various domestic appliances, but the average annual domestic consumption, which is given at round about 850 units, shows a somewhat limited use of appliances of the heavier consuming type.

A record such as this would be of value and assistance to a consumers' department in keeping touch with domestic development, but would necessitate periodical surveys being made on account of the purchase of appliances from various outside sources.

Records of domestic appliances in use in this country are obtainable from the British Electrical Development Association and returns published from time to time in the technical Press, but they mostly represent the larger type of equipment, such as cookers, water heaters, wash-boilers, etc., and possibly a more comprehensive list may be available in the future from additional information collected and supplied by the supply authorities.

PUBLIC LIGHTING

The necessity of adequate lighting to ensure safety on the roads, owing to the increased traffic conditions, has resulted in an all-round improvement in the standard of street lighting during recent years, but in many places it still leaves much to be desired.

Street lighting is largely provided by gas, at least so far as street mileage is concerned, although in the absence of any definite information it is not possible to give actual figures.

The development of the highly efficient gaseous discharge lamp has brought revolutionary changes in street lighting, and extensive use is likely to be made in the future of that type of lamp for street lighting.

Street lighting by electricity lends itself to ease of control from a central point, which would be very desirable in the present circumstances, when it would have been possible under such conditions to have permitted a certain amount of street lighting to be maintained; and it is quite likely that that method of control will receive more attention in the future. The public lighting load has continued to make steady progress during the past few years, and no doubt will continue to do so, judging by the number of roads that still remain to be brought up to the desired standard of illumination.

CONCLUSIONS

It will be realized from the foregoing analysis of the present stage of development that to formulate even some idea of the future possible achievements is virtually impossible, and especially so under the present unsettled conditions brought about by the war, but there is every indication of ample scope for expansion in all the services in which electricity has played so important a part, and there can be no doubt that it will continue to do so.

It is hardly necessary to say that future developments will be governed largely by economic considerations, and much will depend on the price of energy and the extent to which the service can meet the needs of the consumers.

The fact that limited use is being made of domestic appliances is shown by an investigation into the average cooker consumption, which was found to be in the region of 800 units per annum and much less than would be expected judging by the figure given in the example quoted, which worked out at 1½ units per head per day. At a unit cost of 1d. that cannot be considered expensive, and compares favourably with other methods of cooking. The low utilization factor can hardly be attributed to high running cost with the low tariffs available in most places

to-day, and that contention is supported by the results obtained in the case of comparatively small houses occupied by the artisan class. The spending power of the people is a factor to be taken into consideration, and it is estimated that 30 % of the homes in this country can afford to take full advantage of the service, and 70 % or so of the remainder to a lesser extent, so there is every reason to believe that domestic consumption will increase well beyond the present average.

The facilities afforded for hire and hire-purchase of the more costly appliances are reflected in the increased use of cookers, water heaters, etc., and statistics show that one out of seven domestic consumers cook by electricity and 5 % have installed water heaters, representing well over 1 million cookers and close on 400 000 water heaters in service to-day.

In view of the already restricted use of appliances, it would appear somewhat difficult for consumers to comply with the Government's recent Regulations without incurring undue inconvenience.

It is not anticipated that electricity will find favour in large-scale heating of buildings, except under unusual circumstances, on the score of cost, and in the case of dwelling-houses there is the added deterrent of the popularity of the open fire. On the other hand, occasional heating is an attractive proposition, and the popularity and convenience of the electric radiator is such that its use is likely to be considerably extended.

It will be seen from the examples given that increased domestic consumption is accompanied by a higher maximum demand and lower diversity, which affects the cost so far as the supply authority is concerned, and especially on distribution. The only methods of effecting improvements in that direction are either by controlling the load or reducing the loading on the heavier type of appliances, and neither method can be considered wholly satisfactory from the standpoint of service.

So far as costs are concerned, that of production has been greatly reduced since the advent of the grid, but there does not seem to be much prospect of further reductions, which have been checked by the recent heavy increase in the price of coal. The burden of local rates adds 15 % to the working expenses, and the time is long overdue for a revision of the present iniquitous method of assessment based on hypothetical tenancy.

The position with regard to cost of distribution gives rise to some concern, but the problem does not readily lend itself to ease of solution except at the expense of reliability of the service. The degree of reliability expected to-day is high, not only as regards supply but also in servicing, which means expense and must ultimately appear on the consumer's bill, but the desirability or otherwise of effecting economies in either of these directions is an open question.

From the nature of the subject of my Address, it is not possible to enlarge thereon to any extent—it is mostly a collection of facts which may prove useful for reference.

NORTH-EASTERN CENTRE: CHAIRMAN'S ADDRESS

By H. G. A. STEDMAN, Member.*

"ELECTRIC SUPPLY AND THE ORDINARY CONSUMER"

(ABSTRACT *of Address delivered at* NEWCASTLE *23rd October*, 1939.)

It will, no doubt, be agreed that Chairmen-elect of all engineering and allied institutions have this year been faced with abnormal difficulties in the preparation of their Addresses. The international situation has imposed strain upon, and greatly increased the volume of work and responsibility to be shouldered by, all administrative engineers and, in no small measure, by those engaged in public electric power supply.

Furthermore, to-day we face problems and legacies of the past all tending to produce a cramping effect on our industry. Some represent questions of political expediency, others of fashion and prejudice, while again others are associated mainly with financial arguments between those who consider that minimum first costs are a *sine qua non*, and those who take a longer view and endeavour to provide against high maintenance costs in the future.

Fortunately, it should be possible, by the exercise of balanced judgment and experience, to steer a reasonably satisfactory course between these several doctrines and the object of this Address will be to study, briefly, a few of those considerations which may cause the ordinary consumer to react favourably, or otherwise, towards his or her supply undertaking.

It is needless to emphasize that the attitude thus engendered may prove the ultimate measure of success or otherwise when peace comes again.

THE SUPPLY INDUSTRY TO-DAY

In spite of many and varied disabilities, the astonishing fact remains that most supply undertakings in this country have, until quite recently, continued to expand and serve the public with very little, if any, departure from normal, thus giving evidence that, in spite of the almost daily mental unrest caused by the news bulletins, "business as usual" has, in fact, been more than a mere catch-phrase.

There is, however, still room in many directions for further development; we desire not only to retain our present position but also to convince our customers that what we offer is sufficiently reliable and reasonable to merit, in even greater measure, their confidence and co-operation.

It is admitted by all observers that the greatest room for expansion in the supply industry lies in the field of domestic (or more accurately, non-industrial) electrification, a sphere in which, owing to competition and other reasons of a financial nature, progress is most difficult. With industrial problems a case for the utilization of electricity can be presented and either accepted or rejected on economic grounds. Domestic requirements are more intangible, and the case often needs to be presented more from the consideration of the convenience factor.

From the Electricity Commissioners' Returns for 1937–1938 it is stated that sales of electricity per head of the population averaged 419 units, and per domestic consumer connected it was 572 units. That these figures ought to be greatly increased is generally admitted, although estimates of 2 000 to 5 000 which have been publicly forecast appear to be unduly optimistic.

Most of us are, of course, familiar with the admirable propaganda work carried out by numerous undertakings independently and by the Electrical Development Association and Electrical Association for Women, collectively, but many years' experience has convinced me that neither side is yet as fully conversant with the attitude and problems of the other side as is requisite and desirable. Too often the attitude of supply representatives can be summarized in such slogans as "The consumer must be educated in the use of electricity"—certainly a truism—but, alternatively, may not the supplier also need to study with greater insight the viewpoint and experience of the user with the object of improving his own knowledge?

Emphasizing the value of courtesy and good service, an American writer finds that "if you make friends with your consumers, it is apparently with great difficulty that they believe bad things about you."

An attempt will therefore be made to indicate very broadly, deferring, for the present, questions of cost, some of the more important efforts necessary to satisfy the reasonable requirements of the ordinary consumer. These are: Safety, absence of danger from shock, fire, mechanical accidents; continuity of supply, freedom from interruptions for any cause; satisfactory voltage regulation; service, prompt, intelligent, and well-informed; avoidance of offence; strict attention to amenities. Most of these difficulties are in process of being solved, though with varying degrees of success, partly on account of environment and load density, and partly owing to the ever-present struggle to keep the supply industry as a whole on a profit-earning basis, or at least solvent. The density of population, both present and potential, has, naturally, a profound influence on these and kindred problems.

Now that electricity is applied to almost every purpose, operating conditions become increasingly difficult, and whereas until fairly recently it was not a matter of great

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difficulty or inconvenience to shut down a network for a few hours, when necessary, during the night or at week-ends, continuity is now demanded over the whole 24 hours.

Stress is often laid on the argument that any cheapening process only applies to so-called rural areas, but the definition of a rural area is becoming more and more difficult each year that development proceeds. In fact the term, as casually applied, envisages small villages, groups of country cottages, and isolated farms. This, although possibly fairly correct in some districts, is certainly a misnomer when loosely applied to non-urban services. Many relevant instances can be cited where long h.v. lines with solid tee points have been run away from urban and industrial centres as rural non-duplicate supplies, and, in the course of a few years, development has embraced market towns of some importance, mines, quarries and various other industries, each having their own peculiar inhibitions as regards continuity and regulation of supply.

How, then, can these apparently conflicting issues be reconciled? Can it be expected that potential and existing consumers will "burn their boats" and rely exclusively on electric supply for all purposes unless continuity and good regulation can be relied on? Can such requirements be fulfilled by further cutting down the expenditure on mains and apparatus? Surely the reply of all experienced distribution engineers would be a definite negative. Moreover, would not the great bulk of consumers, if the facts were clearly explained to them, prefer a reliable supply, even if it meant a very small increase in the cost per unit to provide duplication or undergrounding?

It would seem, perhaps, that loose generalizations and criticism uttered too openly by persons holding prominent positions in the electrical profession have reached the ears of politicians and the Press, with results which have not always been helpful to the industry. By failing to make reference to the many technical, financial, and legislative handicaps under which we labour, one might assume that such exponents have had insufficient practical contact with that most complex welter of conflicting interests and problems called "Transmission and distribution of electricity."

Reference to parts of the famous McGowan Report may serve to illustrate what, in my view, typifies the facile optimism exhibited by the voice of authority.

The ideal of a "cheap and abundant supply of electricity for all" is attractive, provided it is not associated in our minds with phrases like "rare and refreshing fruit." Probably few people would wish to buy an umbrella with holes in it because it was cheap, and coercion of the supply undertaking would not necessarily induce the public to purchase more electricity than it could afford or make reasonable use of.

Generally speaking, it is a fallacy to assume, as some do, that in the country or non-urban districts the purchasing power of the individual is uniformly less than in the city and town areas.

In these days of easy transport, those who can afford to do so move well out of the congested areas and are able and willing to pay for good services. It is in the thickly populated and so-called lower parts of urban and industrial districts that there is little or no margin for comforts. Demolition of old property and compulsory removal of the occupiers to housing estates and flats, although adding to the number of consumers connected, by no means adds to the purchasing power of these people.

SAFETY

By the 1919 and subsequent Acts, especially that of 1926, which were intended further to regulate and consolidate the position of the supply industry in this country, many new features of profound interest and importance were introduced, the keystone of which was, in the first place, the appointment of Electricity Commissioners. Among their more permanent duties they are, by their Inspectors, required to ensure that most of the conditions for a satisfactory supply will, in course of time, be complied with, at all events by authorized undertakers. These conditions were covered by Regulations drawn up with the advice and assistance of various Committees appointed by The Institution and the electrical industry, and were published in final form as the Electricity Supply Regulations, 1937. These Regulations, together with relative sections of the Amended Factories Act of 1937, constitute probably the most stringent control in the world over electricity supply operations.

Safety, with all its implications, can never be more than a relative term where human nature and human constructions are concerned. It is right and proper, however, to take all reasonable precautions, and these consist, so far as the ordinary consumer is concerned, in making electricity safe for him to use in his home, his farm, and his business, as well as in all places of assembly, and even during the consumer's comings and goings on the highways and by the countryside.

The number of reported accidents collected and issued annually by H.M. Electrical Inspectors and the Electricity Commissioners, while not especially alarming in themselves, indicate that the potential risk in households is not inconsiderable, owing to slovenly wiring and connections, shoddy fittings and apparatus, and a complete ignorance as to the provision and use of suitable earthing. Admittedly the latter is a difficult proposition in some country districts, with present methods of supply. There is, however, no excuse for bad wiring, and the sale of dangerously inadequate accessories and bell-wire flexible cords to the ignorant public is a scandal for which at the moment there seems no remedy. Most undertakings have samples of these abominations in their chamber of horrors. The I.E.E. Wiring Regulations have been accepted as standard, and the only pity is that they are not compulsory. Their primary concern should be safety. Questions of standardization could be otherwise dealt with. So far as the Electricity Commissioners' Regulations are concerned, the mere fact that a certificate of compliance with the I.E.E. Regulations has not been given will not, in itself, justify an undertaker in refusing to give supply.

In the case of hired wiring installations, my company issues a specification to all its contractors, and the work is now followed up during progress by visits from competent inspectors whose duty it is to see that they are complied with. Much interesting information has

come to light through this practice. El.C. Reg. 27(*a*) is permissive in this respect, but it is possible that such inspections may in time be made generally mandatory.

One of the greatest difficulties to be found in making domestic and business premises safe from fire and shock is the practice of consumers to make unreported additions to their installations after they have been passed as satisfactory, and such additions may reduce the safety factor to zero.

Turning to those public buildings where the masses assemble, it is now usual for supervision by independent officials to be carried out, and stringent bye-laws as regards fire precautions and the subdivision of circuits are compulsory. Probably the greatest danger is panic due to darkness, even without fire risk, and it would certainly seem desirable that more extensive use should be made of emergency pilot lights placed at suitable points and supplied by secondary batteries permanently activated by trickle chargers. In all these cases continuity of supply is of vital importance to safety.

Farms require special consideration, the most important point being protection against shock to both persons and stock. How this should be attained is still the subject of active debate. Should all wiring and apparatus be totally encased in metal, the earthing of which often presents great difficulty? Or should insulation of the highest class be relied on without earthing? Alternatively, is transformation to a low voltage the only safe method, and, if so, how low must we go? And how should the large motors be dealt with?

Washing-machine circuits are only too often definitely unsafe, which is the more unfortunate since such machines are in general use on cement and tiled floors; in many cases where circuit defects are discovered and pointed out to consumers they either procrastinate or bluntly refuse to bear the cost of providing a safe circuit. Most undertakings provide free mechanical maintenance of the actual washing machines during hire-purchase periods, and it would seem that legal complications might arise should accidents occur owing to the consumer-owned wiring connections. If statutory regulations are ever introduced, making it obligatory on supply undertakings periodically to inspect and test installations, the consumer would be compelled to rectify any faults found. A small charge would have to be made for this inspection, but the view is held that certain benefits would accrue to both parties. For example, the opportunity could be taken to recommend that idle apparatus be repaired or replaced which, by its re-introduction into service, would benefit the consumer in addition to increasing the sale of energy.

To all those who are seriously interested in these problems, I strongly recommend the study of a report prepared by a National Committee on Statutory Regulations and Registration, issued in book form in February this year. The investigations of this very representative committee have produced enough evidence of an alarming nature to disturb the apathy of even the most optimistic exponents of *laissez-faire*.

During the meetings of the Electrical Contractors' Association last summer, under the Presidency of Mr. Walter Riggs, papers were read from which many important general conclusions may be drawn. Again, many will remember the valuable contribution made by Mr. H. T. Young in his Presidential Address to The Institution in 1936.* All these considerations go to prove that the responsible leaders of that section of the industry are very anxious to effect a progressive improvement in this work, but after every possible precaution is taken there still remains the problem of the inefficient and careless workman, and the promiscuous activities of the average handyman, of both sexes, about a house.

Supply undertakings are reluctant to discuss too freely with consumers the risks attendant on the careless use of electricity, for fear of deterring them from adopting it. One might remark that boat-drill and lifebelts do not prevent many people from going even on pleasure cruises.

The use of electricity is so essentially safe when proper precautions are taken that it would seem a short-sighted policy not to make the consumer a partner in the general desire to avoid accidents.

CONTINUITY OF SUPPLY†

Not so many years ago, when lighting and traction constituted the bulk of the load, a "shut down" for any cause was almost a criminal offence, and an engineer's reputation and prospects suffered seriously if it occurred. Now, with the constantly increasing adaptation of electricity to every conceivable branch of human activity and the consequent increase in annoyance and loss when supplies are interrupted, far from there being a corresponding improvement in reliability, the public in many parts of the country has been subjected to incidents of this nature to such an extent that what is termed a "black-out," unless of lengthy duration or over a wide area, has ceased to be front-page news. This situation has not been overlooked by the gas industry, which, with some success, has adopted the slogan: "Gas never lets you down."

Admittedly, in the more compact areas adjacent to generating stations, supplies are relatively secure. The term "relative security" is used because, for what it is worth, my personal experiences have rather led me to the conclusion that the use of electricity has developed more rapidly than the general technique of supply, which seems, in the main, to have been more concerned with the fractional efficiency of generation and rapid extensions of networks than with stabilizing supply methods and apparatus and reassuring public opinion. Until recently, measures tending towards security of supply, self-imposed or applied by legislation, have had as their main objective the safety of personnel employed in the industry, and only indirectly, and not always favourably, do they affect the ordinary consumers.

Col. R. E. Crompton has stated:‡ "The demand must be controlled by people who study the requirements of the consumers and meet them. . . . The agriculturist is a slow thinker and is deterred from adopting novel methods if he sees that in the hands of some of his neighbours failures have taken place. For this reason distribution by overhead wires in agricultural areas must be so planned, in double circuits, that no single failure of a feeder main can stop the supply in the district it serves."

* *Journal I.E.E.*, 1937, **80**, p. 1.
† See El.C. Regs. 35 and 21(*c*).
‡ *Journal I.E.E.*, 1933, **73**, p. 121

THE COUNTRY CONSUMER

In order to meet the requirements of modern poultry-farmers, the regulation and continuity of supply must be such as to inspire confidence. Incubators of large size—up to 24 000-egg capacity, and hatching some 7 000 chicks per week—are in operation. They provide a useful load with a good load factor in sparsely populated districts, but undoubtedly add to the anxieties of distribution where only single overhead lines are available. Thermostatically-controlled heating of the laying batteries may also become popular during the winter months.

Those interested in agricultural electrification are recommended to read a short article in the March, 1939, issue of *Henley's Magazine*, in which the special problems of the farmer and of village communities are presented in a concise manner. It is estimated that some 40 000 farms in Great Britain are connected to the public supply. Many of these, however, are by no means fully electrified. In this area we have over 1 000 taking supply from the mains.

It is known to all of you that, during the past few years, voluminous contributions have been published in our own *Journal* and elsewhere urging the necessity for reducing costs and tariffs, and we are doubtless all agreed that in the further development of electric supply a good load factor is one of the major issues before us. It would, however, appear impossible for an indifferent and unreliable service to do other than hinder this development; prospective consumers must be offered such quality by duplication or by laying mains underground that they learn to rely on the supply. A cinema full of people turned out half-way through the evening, even in a country town, will cancel out much of the work put in by an enthusiastic sales staff. A dissatisfied consumer is the worst form of advertisement; the fact that he had no breakfast and no hot shaving water will be passed on to his friends.

Have we not over-emphasized the importance of connecting up vast numbers of consumers in the shortest possible time, to the detriment of a policy which would seek more to secure reasonable progress while at the same time consolidating the ground already won? Thousands of consumers may be connected with little improvement in load factor.

It has been well said that "it is not so much the number of connections made or the units sold per head of the population that really matters; the number of units sold per kW connected is a much truer indication of real development."

The ordinary consumer, although varying somewhat in outlook owing to differing environment, is still, in the main, a reasonable human being, and as such is surely capable of appreciating genuine efforts constantly being made by the progressive supply undertakings to provide him, wherever possible, with what he really needs and wishes, at an economic price.

It should be possible for the right type of sales engineer to explain in a convincing way from a technical point of view not only the costly nature of maintaining a reliable supply but also the heavy extraneous costs imposed on the industry (and ultimately on the consumer) by such items as road charges, wayleaves, diversions and local rates, the latter, in various parts of the country, being generally of the order of 8 % of the total costs.

Other points to which attention might be usefully drawn are the increasing burden of taxation, insurances, wages, and materials: the ever-increasing burdens imposed by legislation such as the Meter Acts and the Factory Acts; and the replacement of plant and switchgear necessitated by increased short-circuit kVA on main load centres. All these impose on the unit sold, in the aggregate, a cost out of all proportion to the present-day generating cost.

The cost of maintaining the Central Electricity Board system and the Electricity Commissioners (however desirable these may be) is also borne by the supply industry itself.

These, and many other influences, are almost completely ignored when criticism is directed against the management and organization of electricity supply.

Reference to the Rating and Valuation Act (1928) shows that whereas generating plant of individual industries is subject to de-rating, public utilities plant is specially excluded.

The heavy cost of motor transport, communications, and maintenance staff, together with the high standing charges incurred by the necessary holding of stores and replacements, should receive adequate notice.

THE REGULATION OF VOLTAGE AND FREQUENCY*

"The frequency in the case of alternating current and the voltage declared shall be constantly maintained, subject, as respects the frequency, to a permissible variation not exceeding one per cent above or below the declared frequency, and as respects the voltage, to a permissible variation not exceeding six per cent above or below the declared voltage," etc., etc.

It will be observed that no restriction is placed on the rate of change of voltage within these limits, and the possibilities of creating a feeling of profound dissatisfaction among consumers by affording supplies which complied only with the letter of these Regulations needs no emphasis. Rapidly-recurring variations which may be kept well within these specified ranges will render reading or close work much more trying than slow or gradual variations over the full permissible range. Combined power and domestic supplies, especially on the more remote sections of a network, present problems not easy of solution. A "flick" voltage variation of not more than 2–4 % cannot be cured by step regulators, and is frequently accentuated by them. Such conditions are not indicated on ordinary recorder charts, but can usually be predicted by a knowledge of the various types of power load. Fortunately, on an extensive system these particular conditions only occur in special cases and can be ameliorated by suitable treatment. One of the first essentials in providing level and steady voltage conditions at each consumer's terminals is to concentrate on maintaining, as closely as possible, straight-line regulation at suitable key-points on the h.v. system.

The layout of a system, the type of load dealt with, and the loading conditions, are the most important

* See El.C. Reg. 34(*b*).

factors to be taken into consideration when deciding equipment and routine necessary for correct voltage regulation.

The central control office should be responsible for the day-to-day voltage regulation. By taking into account loading conditions during all periods of the day and the year on the various sections of the system, and by obtaining voltage records, a regulating schedule can be prepared, giving the most suitable voltages to be maintained at key points on the system. This schedule has to be revised periodically, as conditions change.

The main busbar regulation at most power stations is automatic over periods related to the regulating schedule, while the most important regulators at main centres on the system are best operated by supervisory equipment from the system control-room. Other regulating equipment can be operated by attendants at the substations, and automatic regulation is usual on regulators and on-load tap-change equipment which are in circuit on tail-end supplies. In order to make it possible to maintain voltages in accordance with the regulating schedule, continuous indication should be available in the control room from as many regulating points on the system as possible. Supervisory equipments, giving feeder and transformer loading, tap-position indications, control of tap-change equipment and of selected circuit-breakers in main substations, are extremely desirable and save an enormous amount of time and transport on a large system.

For the purpose of further checking voltage conditions at all periods, continuous voltage recorders installed at key points on the system, the charts from which are available in the control office, provide essential data for further investigation.

With regard to voltage regulation generally, it is very important that all new transformers, when installed on the system, should be connected with the correct tappings according to the voltage conditions existing on that section of the system to which the transformer is being connected. By preparing zonal diagrams, preferably coloured and based on the voltage-recorder charts, when new transformers are connected the correct tapping points can be selected by reference to these voltage zone diagrams.

Low-Voltage Network Regulation

Having outlined the basic principles essential in securing steady voltage conditions at scientifically selected nerve centres on the h.v. system under all conditions of varying load, there still remains much important and rather intricate work to be done on the low-voltage networks. The method of approach employed by my company is broadly as follows:—

(1) Maximum Load at Substation

This is returned fortnightly for most network substations, together with the maximum phase loadings on the low-voltage feeders, which is obtained from self-registering maximum-demand indicators. These returns give information as to the general growth of load on the network and substation.

(2) Voltage-Recorder Tests

These are taken over periods of two to three days, during the winter season on networks where loading conditions are likely to produce voltage conditions approaching the limits. The tests taken are as follows:—

(*a*) At substation, low-voltage busbars or (near consumers' premises) recorder tests on two separate phases.

(*b*) At one or more tail-ends where the voltage is likely to be most affected, one recorder on each phase of each tail-end tested.

(3) Records of Distributor Connections in the following form are kept for each network:—

Distributor	Lighting (Domestic)			Lighting (Business)			Heating			Cooking			Power			
	B.	W.	R.	B.	W.	R.	B.	W.	R.	B.	W.	R.	B.	W.	R.	Outer

(4) The data obtained under (1), (2), and (3), are used in connection with the acceptance of new loads on the networks, in regard to substation and network loading, distributor phase-balancing, and voltage regulation.

(5) From the data under (1) and (3) it is possible to calculate the approximate load distribution on any network at time of peak load. For this purpose certain demand factors for each category of connections are assumed. The factors used for any particular network are so adjusted that the total of the estimated distributor loads agrees with the observed substation maximum load.

(6) The data obtained under (5) are used in preparing schemes for network reinforcements where these have been shown to be necessary by voltage tests taken under (2), or by prospective or actual load developments.

Apart from all special tests, approximately 1 000 routine low-voltage charts are taken each year during the period September to May. Each chart covers a period of 48 hours, and the work requires, during these 8 months, 1 light van, 2 testers, and 18 recording voltmeters. Each of the 270 000 consumers connected is fully card-indexed, and voltage complaints received do not exceed one per 6 750 consumers per annum.

It is of some interest to note that a special committee of the Electrical Research Association is at present carrying out investigations on statistical lines regarding the general question of voltage assessment.

Prof. W. M. Thornton, in his Presidential Address to The Institution,* referred to problems of insulation which are not yet solved, and the suggestion has already

* *Journal I.E.E.*, 1935, 76, p. 1.

been put forward that supply technique is, in some respects, lagging behind development.

A few examples may be cited, as follows:

(1) Insulation which will not deteriorate under heat, mechanical and electrical stresses, and is completely non-hygroscopic.

(2) Control of lightning effects. Mr. Winfield predicted it would be solved in 5 years. This period has now expired, and, judging by this summer's results, no economic solution has yet been arrived at.

(3) Earthing on low-voltage network supplies, where soil resistances are high, is still in a chaotic state. The most satisfactory solution, wherever possible, would be to place the network underground and to earth the cable sheaths at sufficiently numerous points. Where overhead networks are necessary, a continuous earth-wire earthed at sufficient points would appear to be the best solution.

At the International Conference held in Paris this summer, papers covering a wide range of subjects were presented, many of which dealt with electrical problems not yet fully solved.

During the preparation of this Address, a considerable amount of technical data and figures of costs was collected for the purpose of supporting certain of my arguments. In the present unhappy circumstances, however, it has been deemed inadvisable to include them.

Let us confidently hope that, when this present reign of madness is over, engineers will once more be able to devote their energies to building up and consolidating a truly "electrical age."

Such anomalies as "Consumers' Associations" with their "Parliamentary Watchdogs" will then be a comedy of the past, because suppliers and consumers will have voluntarily entered into a bond of complete mutual understanding and confidence.

They will be pledged to the removal of anomalies, to the improvement of quality and reliability, and, in co-operation with public authorities, to the mutual effacement of those disfigurements which the artistic nature of all cultured people instinctively abhors.

Let us hope that when this ideal condition shall have been attained, all those men and women of vision who have laboured towards its achievement will gain that most satisfying reward of all—the gratitude of their fellow citizens.

NORTH-WESTERN CENTRE: CHAIRMAN'S ADDRESS

By O. HOWARTH, Member.*

(*Address delivered at* MANCHESTER *4th November*, 1939.)

It is natural that a considerable proportion of my Address should be devoted to the electricity-supply industry, with some reference to the functions of a supply undertaking's testing department. I also want to discuss the relations between user and manufacturer and between their points of view.

THE SUPPLY INDUSTRY

As our social organization changes—and I think we are all vividly aware that it is changing—it is inevitable that the organization of the supply industry should change also. When public supply was first commenced there were serious limitations to the distance from the power stations at which a satisfactory supply could be afforded. One result of technical progress is that there is no technical limit to the distance between the power station and the user in this country. The practical result is that many of the earlier supply areas are very inadequate as organization units to-day.

The future growth of the electricity-supply industry is dependent upon two main factors:—

(1) the growth of population, and

(2) the increased penetration of electrical methods. We are told that the population is now practically stationary, so we cannot expect help from that direction. With regard to (2), we are in intensive competition with other methods of carrying out the same operations, both in the home and in the factory. In many cases these alternative methods have the advantage of being long-established, and in consequence the electrical method is regarded as an untried novelty. One of the greatest obstacles to electrical progress is the inherent conservatism of the average man and woman. We dislike changes and are disinclined to make any radical alteration in our household arrangements. I find many electrical engineers are about 20 years behind the times in their knowledge of domestic electrical apparatus and the cost of its use. There is evidence that enlightenment is spreading even amongst them. It is noteworthy that papers on the utilization of electricity in domestic premises draw audiences which are amongst the largest.

Supply undertakings are being pressed from all directions to acquire more, and still more, business. The Electricity Commissioners, the Electrical Development Association, the Press, the manufacturers and the Central Electricity Board, all take a hand. We are expected to go on connecting more consumers each year than we did the previous year, despite the fact that if we manage to do this we shall in a few more years have far more consumers than there are premises. Many of the houses built to-day are to replace older houses which are being demolished, and in spite of the present building activity the percentage rate of increase is very small. We already afford a supply to 64 % of the existing premises, so the limit to the number of consumers is about 55 % above the present number with a stationary population. Under the circumstances we must look to an increased use of electricity amongst our existing consumers for development of supply. Tariffs are an important factor in development, but they are not the only factor. Rates are an important factor in the cost of living in a particular district, but the cost of houses is still more important. In the same way the cost of electrical apparatus is an important factor in the cost of using electricity in the home. The annual cost of an electric cooker is about the same as the annual cost of the electricity it consumes. The cost of lamp renewals is equivalent to about ¼d. per unit consumed. Radiators are among the cheapest appliances in first cost and upkeep: and the purchaser has the choice of a wide range from the highly ornamental to the really cheap but effective ones. A multitude of designs are available to suit all tastes and pockets, and the cost of upkeep of radiators in fairly continuous use is remarkably low with modern elements.

It is becoming the practice to put lighting and at least one socket-outlet in council houses built to replace condemned property. In better-class houses more socket-outlets are installed, but in my opinion the I.E.E. Wiring Regulations, which call for a separate sub-circuit for at least each pair of 15-ampere socket-outlets, discourage the provision of reasonable facilities by making them unnecessarily costly. I see no reason why a 15- or 20-ampere sub-circuit should not be used to supply three or four 15-ampere socket-outlets which are all situated in one room of normal size in a house. It is a great convenience to be able to plug a 2- or 3-kW radiator in different positions, and it is obvious that the total load in a living room or bedroom is not going to exceed 3–4 kW. With the type of flat-pin plugs so popular in this area, 5-amp. and 2-amp. fused plugs controlling 1-kW radiators, lamps, wireless sets, etc., can safely be plugged into the tops of the 15-amp. plugs, or direct into the 15-amp. socket-outlets, and such an arrangement is inexpensive, safe and very convenient, although the Wiring Regulations preclude the use of flat-pin plugs. I sincerely hope that the Regulations will not be changed from their present voluntary status unless, and until, they become far less academic and much more realistic so far as domestic premises are concerned. If they should become compulsory in their present form they would undoubtedly be a serious obstacle to domestic electric development.

Much has been said about the ability of the people at the lower end of the income scale to afford to use electrical

* Lancashire Electric Power Company.

appliances. When one realizes that 75 % of the families in this country have incomes below £250 per annum, it can be appreciated that there are an enormous number of houses in which electricity can only be used if it is as cheap as or cheaper than alternative methods, and that the coal fire must be used to the fullest possible extent for cooking purposes. With the prices charged for electricity under most two-part tariffs in this district, an appreciable saving can be effected by using electrical methods of cooking and heating and dispensing with the coal fire during the summer months. The real difficulty lies in the provision of suitable apparatus. I shall refer to this later.

LOAD BUILDING AND TARIFFS

In considering tariffs we must have regard to the growth of electricity supply from its early beginnings when it was a new method of obtaining artificial light. The early pioneers charged a price per unit which was sufficient to cover their standing charges and their running costs, provided the consumption came up to anticipations. As a result, the custom of charging a fixed price per unit for electric lighting has continued to the present day, although there is a strong tendency for lighting consumers to-day to take advantage of some form of two-part tariff. The actual running cost of supplying the units is naturally a very small part of the price per unit on a flat-rate lighting tariff. Electricity is a commodity and in many respects is like all other commodities which are sold in the ordinary way of trade. With all commodities, the price must be fixed between an upper and lower limit, the upper limit being the value to the purchaser and the lower limit being the cost of providing and delivering the commodity to the purchaser. If the cost delivered is, or becomes, greater than the value to the purchaser, the trade ceases. Competition invariably brings the price down to a figure approximating to the cost of providing and delivering.

Whilst supply undertakings have a monopoly of a kind, i.e. to lay cables in public thoroughfares, it is not the kind of monopoly which eliminates competition and is by no means similar to the monopoly which a water-supply undertaking has. If you build a house you are compelled to put in a water service from the water-supply authority and you must pay the price which they demand; but you need not put in a supply of electricity as there are alternative sources of lighting and heating available everywhere.

The two-part tariff, as it is termed—i.e. a tariff where one part consists of a fixed charge which is to cover management costs, including meter reading and accountancy, and other standing charges, and a running cost which is dependent upon the number of units consumed—is the most satisfactory tariff for ordinary domestic premises. It caters automatically for increased use of electricity, and the same tariff schedule can be applied to a user of 100, 1 000 or 10 000 units per annum.

One of the supply undertakings' difficulties in dealing with ordinary domestic consumers is that the undertakings engage in a form of retail trade where they must keep in contact with each individual customer, yet many of these customers do not bring in a revenue of more than £3 a year, whereas the average shopkeeper receives much more revenue than this from his regular customers, and in many cases he never has to visit their homes.

The supply industry is frequently criticized for having a multiplicity of tariffs, but what people really criticize is the multiplicity of prices, as almost all undertakings offer the choice of a flat rate or a two-part tariff to domestic consumers. Naturally the prices vary in different areas, but so do the prices of most commodities. The Milk Marketing Board frequently makes a difference in its price of ½d. a quart between the Manchester area and the Bolton area. Cinemas in the West End of London charge about 3s. 6d. for a seat which costs 2s. in Manchester and 1s. in Bolton. Like these commodities electricity has a different value in different places, and the cost of affording the supply is different, hence the differences in prices. Supply undertakings are also criticized for having a great number of different prices for different purposes. Both the value to the user and the cost of supplying vary with the quantity of units taken, with demand, and with diversity. Number of units, demand, and diversity, are largely dependent upon the purpose for which electricity is used, and therefore different prices are offered for different uses. This results in a considerable number of different prices being offered by each individual undertaking, but any particular class of customer has usually only the choice of the two-part or flat rate for his particular purposes, and therefore the schedules are not unduly complicated unless all the prices are published on one schedule. For instance, it is no use telling a domestic consumer what the off-peak heating or industrial refrigeration tariff may be, and those undertakings which make a practice of publishing tariffs for the ordinary domestic, shop, and small-power user on their schedule and quoting other tariffs only to those interested, find no difficulty in dealing with the consumers on this score. Incidentally, picture houses charge different prices at different times.

Electricity is subject to the ordinary economic laws governing the supply of commodities, but its nature is such that the various factors in the cost are in different proportion to what they are in the general run of commodities. Much of the criticism of the tariffs of supply undertakings comes from those who are ignorant of the distributing and selling technique of the supply industry.

Whilst it is true that load cannot be built without suitable tariffs, it does not follow that because the tariff is suitable the load will grow automatically. I venture to predict that if the undertakings of this area offered electricity for cooking free to all those domestic consumers who purchased and installed a conventional *de luxe* cooker suitable for 4 persons, it would be many years before 50 % of the domestic consumers were equipped with electric cookers. If a similar offer were made with regard to 1-kW radiators, the response would be rapid and considerable. The reason for the difference in response is that radiators which do their job quite well can be purchased for 10s. or even less. A satisfactory cooker suitable for 4 persons will cost more than £10 to buy, and another pound or two will have to be spent on the necessary wiring. That simplest of cooking devices, the griller, frequently called the breakfast-cooker to make it appear worth more, costs the consumer about £2 and is very limited in its functions. Domestic load-building

demands that the policy adopted in radiator design and manufacture shall be adopted in the design and manufacture of cooking appliances. I sometimes think that the breakfast-cooker is so called because it is so unsuitable for warming the milk for supper and so utterly incapable of cooking chipped potatoes for high tea, and yet it can be designed to perform these two functions quite as well and almost as rapidly as the latest electric boiling-plate, without in the least impairing its function as a griller. It is not necessary to have a massive cast-iron top or to bury the element amongst a mass of refractory material as is done in the conventional griller. Nor is it hygienic to compel the user to cook the food in a little black box with uncleanable corners and in which greasy dirt cannot be detected. A light, open frame in which the griller unit sits would be far more suitable, and the griller itself should have the minimum of refractory material necessary to support the elements. The top should be of thin sheet metal, probably stainless steel, suitably designed to permit quick transfer of heat from the elements to utensils placed on top. Experiments have shown a griller-boiler designed on these lines to be thoroughly satisfactory as a griller and as a boiling-plate.

I doubt if it is generally realized that the unsuitability of the conventional griller for boiling and frying is doing considerable harm to the supply industry by discouraging councils from relying solely upon the electricity service in their houses. They install a gas boiler and an outlet for a gas ring, whereas if we were able to offer a good cheap griller-boiler which would be used for boiling and frying, many more electric wash-boilers would be installed. I am aware that the griller-boiler with the sheathed tubular element gives far more satisfaction in use than the more conventional type, but in my view this is due to its effectiveness for boiling and frying. It is not very satisfactory as a griller, and its initial and maintenance costs are beyond the reach of the low-income household.

There is scope for considerable modification in the design of electric ovens. At present they are only available as part of a complete cooking equipment consisting of oven, grill, and one or more boiling-plates, and the cost of the equipment is such as to take it quite out of the reach of the lower-income household, unless it is heavily subsidized. It is perhaps not generally realized that the advent of the oven thermostat enables considerable departures to be made from the conventional design of electric oven. The " three-heat " oven control provides for a high pre-heating loading and two cooking loadings, marked " medium " and " low." It is obvious that the requisite temperature for many cooking operations must be obtained by changing the switch between medium and low at appropriate intervals. This would result in considerable temperature variations if it were not for the heat-retaining capacity of the lagging behind the walls of the oven and the masses of metal used in the cooker construction. These act like a sponge, absorbing heat and thus preventing a rapid rise when the switch is turned to a higher loading, and releasing heat and preventing a rapid fall when the switch is turned to a lower loading. It is this heat capacity in the lagging and frame which is responsible for the long preheating time of the electric oven, because it must be filled up with heat as the air in the oven warms up. An oven was constructed with a fairly thin liner in a sheet-metal outer case with about $\frac{3}{4}$ in. of air lagging in between. The preheating time was only half that of the conventional design of oven of the same capacity. The watt loss to maintain any temperature within the cooking range was less than 10 % in excess of the loss in the conventional cooker, with the result that there was an actual saving in units on the majority of cooking operations. Such an oven would be unsatisfactory with three-heat control, as the user would have to switch up and down so frequently for most cooking operations, but when fitted with a thermostat its operation is as simple and satisfactory as that of the best automatic oven of conventional design. Such an oven can be constructed very cheaply, even when fitted with a thermostat.

If we are to develop the electric cooking load in the lower-income houses, it is imperative that we should have available these cheaper but none the less effective cooking appliances. The alternative is to subsidize the conventional type of cooker so heavily that the cost of electricity will not be so low as it otherwise would be. The effect of uneconomic hire cannot be judged from present conditions because few undertakings have hired cookers to more than 10 % of their consumers. To induce 50 % of their consumers to hire cookers would probably require a considerable reduction in the hire charge, and the magnitude of the resultant subsidy would undoubtedly be reflected in the price of electricity.

Assuming that the apparatus must be hired or sold at an economic price, how are we to develop the cooking load? I believe that we could do much by offering a griller-boiler of the pattern which I have described previously, a low-price quick-boiling kettle such as is now available in aluminium or enamelled iron, without feet, so that it can be stood on top of the griller, and a separate oven built upon the lines I have indicated and upon which the griller could stand if desired. Each appliance should have a similar connecting socket so that one socket-outlet and one plug and flexible cord could be used for each appliance. The inability to use more than one appliance at once would not be a serious limitation and would enable the one outlet frequently provided to be used, thus avoiding the need for a special circuit to be run. One advantage of such a combination would be that it could be purchased in stages. When a consumer has a griller and wishes to have an oven also, he must dispense with his griller and replace it with a cooker incorporating an oven and a griller, which discourages him from making this change. As only about 10 % of the consumers in Great Britain have electric cookers, it is evident that the market for the conventional cooker is strictly limited and that only a small proportion of the potential cooking load can be obtained unless and until we can offer more effective cooking appliances at a price more in accordance with the spending capacity of the lower-income householders.

FUNCTION OF TESTING DEPARTMENT OF SUPPLY UNDERTAKING

The function of the testing department of a supply undertaking which is most to the fore at the moment is the certification of meters. It was inevitable that the Electricity Supply (Meters) Act, 1936, should cause a

modification in the routine for handling meters, and that it should compel those undertakings who had spent little or no money on meter testing in the past to provide the necessary accommodation and equipment to enable their meters to be properly tested. The amount of apparatus and instruments which the Commissioners specify for a testing station is not in any way unreasonable, but their rigid requirements as to type and performance of instruments are, in my view, unreasonable and unnecessary. They are unreasonable because they rule out the use of certain very good instruments and thus penalize well-equipped testing stations of long standing: there is a clause in the regulations which empowers the Commissioners to approve any instrument or apparatus which they deem suitable for its purpose, but in practice they generally approve such apparatus for a limited term of years. The Commissioners recognize two classes of testing station—those with a potentiometer, which they designate class A, and those without a potentiometer, which they designate class B. They take no cognizance of the ability of the staff to use the apparatus properly, which is manifestly absurd. They endeavour to ensure accuracy by regulations which impose unnecessary restrictions upon the testing stations which are well equipped and competently staffed, thus increasing the station's costs and at the same time reducing rather than increasing the accuracy with which they make their measurements.

When the examiner calls to certify meters he selects not less than 5 % of those awaiting certification and tests them against the station's wattmeter, and if they are within the legal limits and agree reasonably well with the errors shown on the certificate, he certifies them. Note that the wattmeter he uses may be the one used when the meters were tested by the undertaking's own staff, and that he is therefore checking the consistency rather than the accuracy of the meters. It would be more satisfactory if the examiner brought his own wattmeter, as his tests would then constitute a check upon the *accuracy* of the testing carried out in the station. Curiously enough, the examiner does bring his own stop-watch, which seems unnecessary as the undertaking's watches can be checked before and after use against the standard clock which must be provided.

All instruments must be sent to the National Physical Laboratory for approval, and thereafter checked at specified intervals against the potentiometer, which in turn must go to the N.P.L. every 2 years. The principal object of sending wattmeters to the N.P.L. is to enable the latter to make sure that the errors obtained when tested with direct current against a potentiometer will be the same when the wattmeter is used on an a.c. circuit. Many testing stations have the necessary equipment to make this test themselves to a sufficient degree of accuracy on 6-in. substandard wattmeters, and it is an unnecessary hardship to have to send every substandard wattmeter to the N.P.L. It is a serious matter to send delicate instruments on a 400-mile journey, and the risks are such that the instrument must be retested in the testing station before it is put into use. Another difficulty is that the instrument may be unsatisfactory for the use to which it is to be put, due to a self-heating or fatigue or phase error which, whilst within the specified limits, may introduce errors in use. Manufacturers of these instruments are usually quite willing to remedy these defects, but as it involves re-approval by the N.P.L. at a cost of about half the price of the instrument, undertakers are likely to take the view that the instrument is officially approved and must be used as it is, and in consequence the accuracy of testing is degraded.

It would, in my view, be more satisfactory, would cost the industry less, and would make for greater accuracy, if the Commissioners would recognize a higher grade of testing station in which suitable standards are provided and which has an adequate and competent staff to use them. Such stations should be permitted to test their own substandard instruments, and those of other testing stations in the vicinity. This would reduce transport risks to a minimum. When I hear of some of the rules to which the examiners work, I wonder whether the Commissioners have forgotten the limits of $2\cdot5\ \% +$ and $3\cdot5\ \% -$ to which we are working on the ordinary commercial meter.

The other functions of a testing department vary considerably on different undertakings, but some of the more important ones are worthy of mention. On a large undertaking with a considerable transmission system and a number of high-tension distribution networks, the correct functioning of protective gear is of vital importance. It falls to the lot of the testing department to make laboratory and site tests of relays and protective equipments and to ensure correct grading of settings and time delays. The investigation of system phenomena and acceptance tests on electrical plant are frequently carried out by the staff of the department.

In recent years it has become the practice for testing departments to investigate the performance of domestic appliances which the undertaking sells or hires to its consumers. The importance of this cannot be overemphasized if the appliances are to satisfy the consumers by their performance and reliability. Type tests must be made on samples to determine the performance, and routine tests to ensure that each appliance is within tolerable limits of performance. Considerable skill and experience is necessary to enable satisfactory type and routine tests to be devised. In many cases the results cannot be measured but must be judged, and it is difficult to devise methods of judging which are consistent from day to day and which eliminate personal bias. It helps in designing these tests if a close watch is kept on the reactions of the customers to the performance of appliances, although this is difficult because the views of consumers who may dislike some particular feature are usually exaggerated out of all proportion to their importance, whilst the satisfied customer is generally silent. Reports of demonstrators and sales staff give a good indication of the response of the public to appliances, provided a sufficient number of reports are taken to give a fair sample. Criticisms of appliances by customers and demonstrators are valuable in indicating necessary modifications in performance tests.

It is not possible to judge the reliability of appliances without the aid of a statistical analysis of faults occurring in service. It need not be costly to obtain and if organized on simple and cheap lines—as it can be—it will more than pay for itself by clearly indicating the most

prevalent faults. Without it one gets a wrong impression and is apt to spend much time and thought endeavouring to remedy a relatively infrequent fault, whilst ignoring entirely a fairly common fault because it has got to the stage of being a common occurrence without much note having been taken of it in the early stages.

The testing department sometimes takes a large share in staff training. The technical nature of much of the work provides ideal experience for the trainee, and the varied nature of the duties enables the qualities of trainees to be assessed with a fair degree of accuracy. This will help to avoid putting square pegs into round holes, which is good neither for the staff nor for the supply industry. Large manufacturing concerns have found it necessary to organize the training of their junior staff in order to ensure a competent senior staff thoroughly conversant with their organization in the future. I think the time has come when the larger supply undertakings should seriously consider whether they can afford to acquire their staff in the old haphazard way, or whether it would not make their organization much more efficient if they carefully selected and trained their junior staff, and filled their more senior positions from amongst those whose qualifications and suitability were thoroughly understood.

RELATION OF USER AND MANUFACTURER

One often hears users of electrical apparatus criticize manufacturers for defects in their designs, and manufacturers criticize users for insisting upon modifications to their standard patterns. Probably both sides have a legitimate grievance. There are two methods which appear to be commonly adopted by manufacturers. One is to design something, put it on the market, and then persuade prospective users that they need just that. Marketing is costly but sometimes effective. Outstanding examples are the Kodak camera and the Hoover vacuum cleaner. The marketing methods adopted for these articles have been very expensive but so effective that people refer to a " Kodak " when they mean a camera, and a " Hoover " when they mean a vacuum cleaner. The number of unsuccessful attempts to copy the methods of these two firms are probably legion, and these attempts are to some extent responsible for the prevalence of the idea in the minds of manufacturing engineers that users are not amenable to reason. The other method is to produce something to meet a need. Knowing the existence of the need the manufacturer produces something which meets his conception of the need, and he is surprised and disappointed to find that the prospective user's conception differs from his own. On the other hand, it is very easy to criticize, and purchasers are in a privileged position and must be listened to with patience, although the views they express may be ignored. In this age of specialization and rapid change it is not possible for the purchaser to appreciate all the difficulties of the designer and manufacturer, and in consequence the manufacturer comes in for a certain amount of unreasonable criticism.

The supply industry is the user of much plant and apparatus, and acts as the link between the manufacturer and the user of domestic appliances.

It is the function of the user of plant and apparatus to determine his requirements in detail and then ascertain how closely his requirements can be met by the use of standard products. He must then decide how far he can modify his requirements to enable standard products to be used, or, alternatively, how much he is prepared to spend on having his special requirements met. Having specified his requirements, he is entitled to expect that the apparatus put forward by the manufacturer will meet them. Unfortunately, due to human fallibility, complete freedom from mistakes is not to be expected, and reasonable precautions must be taken by the purchaser to ensure that the apparatus supplied meets his requirements.

It is the function of the manufacturer to design plant and apparatus to meet the requirements of the users. He is faced with the problem of standardization in the interests of cheapness and reliability, but standardization of design is dependent upon standardization of requirements. This latter is naturally difficult to achieve in an industry where technical progress is so rapid. Co-operation between supplier and user is in the interest of both parties, and whilst the British Standards Institution exists for this purpose, it cannot, in the nature of things, cover the whole field. I do not doubt for a moment that there already exists a considerable amount of close co-operation between supplier and user of electrical plant and apparatus, because most engineers recognize that two heads are better than one, and that both parties have much to gain from hearing the views of the other.

As a user I can, perhaps, speak with less hesitancy about my fellow users, and I am compelled to admit that there are some who shut themselves off in a world of their own, insist upon certain requirements being met, and refuse to listen to any criticism of them. We are all apt to think that our own way of running our job, whatever it may be, is the best way. Many of us have gradually developed an organization to meet growing needs and changing circumstances, and we naturally think that everything within the organization is carried out in the best possible way and for the best possible reasons. Some of the methods adopted were developed years ago, and because they appear to have worked well we have seen no reason to change them. It is most refreshing occasionally to be asked to justify our methods, as one discovers that the principal merit of some of them is that everyone in the organization is familiar with them; and that, on balance, other methods would have been equally satisfactory. Such experiences make us realize that even manufacturers may be justified in suggesting some alternative scheme to the one detailed in our inquiry, and that their views can be quite helpful.

The relationship between the supply engineer and the manufacturer of domestic appliances is in a different category. The supply engineer is an intermediary between the manufacturer and the user, and the issue has been confused by the subsidized hire schemes of supply undertakings. These hire schemes have compelled the undertakings to pay great attention to reconditioning, and this has had considerable influence upon their specified requirements. On the whole it has, perhaps, tended to limit the scope of the manufacturers and thus to discourage the production of the cheaper type of appliance. It is significant that radiators and irons, which are not usually hired, are available in cheap lines, whereas cookers, the great majority of which are hired or hire-

purchased through supply undertakings, are not yet available in cheap lines. I am afraid that the quest for reliability and reconditioning facilities has overshadowed the requirements of the user to an extent which has definitely retarded the development of these appliances along lines which would best meet the needs of the user. Perhaps a good illustration of this tendency is the attitude of many supply undertakings and manufacturers to the thermostatic control of electric ovens. The undertakings feared to offer an improved oven lest it should make their existing cookers obsolete and thus involve them in loss. The manufacturers were equally reluctant to offer a facility which would compel them to redesign their ovens and thus render many of their patterns obsolete. The views of the users are compelling both manufacturers and undertakings to substitute automatic oven control for the old-fashioned 3-heat control in the cookers they offer to the public.

It is the function of the supply engineer to ascertain what the user wants and what he can afford to pay, and to pass the information on to the manufacturer. Co-operation between the two would, I am sure, result in the requirements of the user being met much more effectively than at present, and at an economic price.

THE ENGINEER AND MANKIND

All enlightened beings have a duty to use their special gifts and specialized knowledge in the service of mankind, and engineers will not wish to be absolved from this duty. As our leisure time is strictly limited, we can only fulfil our responsibilities effectively if we are animated by the spirit of service in carrying out our everyday duties. Fortunately, or unfortunately, the social framework in which we live compels us to concern ourselves with obtaining a reasonable material standard of living for ourselves and those dependent upon us, and if we are not careful we may allow this need to dominate our activities. Most of us are servants of an organization which is run along commercial lines, and our opportunities for service are governed to some extent by the policy of those in control, but however much that policy may limit us I think that we, as individuals, do render service in so far as we use our skill and knowledge to the full in doing our job. If those who determine the policy of the organization which we serve make service an important factor in their policy, our opportunities are undoubtedly increased and our responsibilities are correspondingly greater.

We all have some leisure, and we must use some of it to keep ourselves in touch with matters outside our own profession if we are to avoid becoming narrow-minded in our outlook. Otherwise, our outlook on matters outside our profession will become of no value whatever and we shall be quite incompetent to fulfil our obligations as citizens of a democratic country. The severe demand made upon our time and energy during our training period constitutes a danger, as we are to some extent prevented from devoting attention to the problems that beset mankind during the formative years of our life.

We have just entered a period of war, war made more terrible and devastating by the progress in science and engineering. In fact, there are some who blame the scientists and engineers for the present state of the world. But surely we are no more responsible than others outside our profession for our present circumstances. We are, however, equally responsible as citizens with those others for the prostitution of our skill and knowledge to such devilish purposes, and we should be sufficiently far-seeing to realize that we owe voluntary service during our leisure time, war or no war; service to ensure that moral progress keeps pace with engineering progress and that the outcome of our skill and knowledge shall be the service and not the destruction of mankind.

SCOTTISH CENTRE: CHAIRMAN'S ADDRESS

By Professor S. PARKER SMITH, D.Sc., Member.*

"ENGINEERING EDUCATION AND PROFESSIONAL INSTITUTIONS"

(*Address received* 16*th September*, 1939.)

For this Address I find I have the choice of two subjects if my remarks are to be restricted to knowledge gained through experience—design of electric machinery and education of electrical engineers. The former subject is attractive because it excludes any personal element, and because success or failure can be judged impartially by results. Alas, the interest in electrical design is so relatively confined that it has now to fight for a place in a teaching curriculum; while in a Centre numbering so few designers the subject must have a limited appeal. Electrical engineering education, on the other hand, interests everyone and is of vital interest to The Institution. If proof were needed, it was amply given at the recent informal discussion at this Centre. The drawbacks in such a choice are many. Opinions, though tenaciously held, are sharply divided. Facts are obscure and hard to establish. An endeavour to be strictly impartial would probably result in meaningless platitudes; while strong advocacy of one's own viewpoint is scarcely becoming in a Chairman's Address.

THE INSTITUTION'S EDUCATIONAL REQUIREMENTS

Perhaps the safest plan is first to consider the educational requirements for Corporate Membership of our own Institution. Put rather crudely, we may say that an Associate Member is one who has the practical experience of an Associate plus the educational qualification of a Graduate. We therefore consider the latter.

The educational avenues to Corporate Membership may be roughly divided into three groups:—

(*a*) A recognized Degree or Diploma of a college or university (usually obtained after full-time courses).

(*b*) Recognized Ordinary and Higher National Certificates (usually obtained after part-time courses).

(*c*) The Institution Associate Membership and certain external Examinations, such as the City and Guilds of London Institute Final Examination in Electrical Engineering Practice, accepted in part or in full.

Evidence of success in an English paper is compulsory.

On the average, The Institution recruits about one-third from each group.

In passing it may be mentioned that the fraction is much the same in the Associate Membership entries of our sister Institution, The Institution of Mechanical Engineers.

Avenues (*a*) and (*b*) are sufficient to indicate the importance of all engineers in training following a recognized course.

Naturally, along with educational qualification, practical training, in addition to responsible practical experience as an electrical engineer, is insisted upon—we shall return to this later.

In approaching the ways and means of educating electrical engineers, I would suggest at the outset that the courses should conform to The Institution's requirements, provided always that these requirements have been formulated after careful consideration of the ability of the colleges to give them effect. If there is not conformity then adjustment is needed, for corporate membership of the professional Institution should be the aim of every newcomer.

FULL-TIME COURSES

These include degree, diploma, associate, and certificate courses extending over at least 3 years. It would be well to examine how far college courses meet the requirements of The Institution and practice. For some years there has been a tendency to develop Honours courses extending over 4 years. Admitting that the men who are to form the backbone of our profession should take a properly devised college course, two facts can be stated regarding the majority: firstly, they are not of Honours standard; secondly, 4 years is too long for them to spend at college. Also for Honours students, the first year of a 4-years' course should be omitted if the work has already been done at school. Where there is but one course, and that an Honours course, it follows that the bulk of the students get a course for which they are not suited. The consolation award of a Pass degree is not a remedy for ill-digested knowledge, nor is the award of a Pass degree in the penultimate year of an Honours Course a good solution when the curriculum is misconceived. A course beyond the capacity of the student has a demoralizing effect. What the average engineer needs is a more general training. Unfortunately universities are seldom staffed or equipped for separate Honours and Pass courses, or for both degree (4-year) and diploma (3-year) courses. On the other hand, large technological colleges, equipped to meet the needs of evening students, have adequate staffs and can offer such alternatives. This fact opens up new possibilities.

TECHNOLOGICAL INSTITUTIONS

In many university towns there is also a technical college or technological institution, and where degree courses are given in the college the degrees are conferred by the local university under some form of affiliation scheme. In such cases there is mostly overlapping and waste. Generally speaking, an engineering course in a

* The Royal Technical College, Glasgow.

university is a heavy drain on university funds, and the cost per student is out of all proportion to the cost per student in the departments in arts and science. Not only are at least a professor, lecturer and demonstrator needed, but an expensive laboratory with at least one mechanic.

Consider the advantages which would accrue if the technical college were made the technological department of the university. Economy would result through the transfer of engineering students from the university to the college, thereby affording relief to the university finances; the college with its large resources could readily absorb the inflow from the university. Alternative degree and diploma (or honours and pass) courses could be offered without inconvenience; the resultant strengthening of the college would justify increased equipment and a more expert staff.

Students would greatly benefit from improved tuition in the form of tutorial classes, etc.; technological institutions would be under university control rather than under municipal control. The desirability of concentrating technical work in one institution should be viewed on broad lines, for matters such as vested interests distort the outlook. The general issues would seem to be the adequate provision of properly trained engineers, economy, and possibly regard to future needs in a falling population.

Owing to its size, London would need more than one technical institution; otherwise the principle of withdrawing engineering from colleges where students are trained for the teaching, legal, medical and other professions, could be applied.

RESEARCH WORK AND SPECIALIZATION

It is doubtful whether the normal educational institutions should attempt too much in these directions. Their proper function is to educate students, and if they do this they do well. Large-scale and long-term engineering investigations are essentially a matter for the works, for development departments, and for research institutions. The limited resources of a college for such engineering research work soon become apparent; though, of course, much useful work in the way of measurement and testing can be done. A practical approach in colleges to research is to train selected men in the methods of research. Apart from the difficulties in carrying out costly and lengthy experimental research in colleges, there is a possible danger of depriving undergraduates of proper tuition. Both professors and lecturers have usually enough to do in their normal work, and, unless provision is made for other activities such as research and testing, the efficiency of teaching work will be reduced. It should be remembered that teaching is the work for which the staff is primarily employed, and that the needs of the average student are met by concentration on the eternal verities.

As regards specialization, we are repeatedly told by employers that they do not want it in the curricula. Most employers—at least large employers—say quite plainly that they want men well-versed in the principles of engineering science. Firms requiring assistants with specialized knowledge should not seek them among ordinary college graduates. The objections to specialization in undergraduate courses are obvious. Essential matter is likely to be crowded out, since the time is fully needed for fundamental subjects; it is only in rare cases that a young engineer knows what will be his future work in the wide electrical world, so that the courses should be framed on as general lines as possible, leaving specialized training for the works or for post-graduate study; except for basing course work on practical data, the specialized information imparted in an undergraduate course is likely to be useless, as being either obsolete or inadequate for commercial competition.

INTERNAL COURSES OF STUDY

The advantage of such courses over private study and correspondence courses is largely in the personal element, but this may be lost unless fully developed. During the session, the students should be in constant communication with the staff. Two obvious means are the laboratory and the tutorial class. The usefulness of the tutorial class should not be overlooked. For at least 1 or 2 hours per week the students of each class should be given exercises in the form of analytical or graphical problems on the lecture work. During these hours members of the staff should sit alongside the student to give any necessary help in his problems, also to discuss any points about laboratory reports, etc. A properly-conducted tutorial class is not to be confused with spoon-feeding or cramming for examinations. Again, at least every term the student can be invited to the professor's room, when all matters concerning college and practical work can be talked over. This enables the professor to keep a record of each student's progress and activities.

Importance should be attached to all course work, and for it credit should be given in the final result. For this purpose each laboratory report, each problem, and each drawing, should be as carefully marked as the examination script. If this is done, one great criticism against cramming and the unfairness of examinations is removed. Failure to do this places the course midway between an internal and an external course, by permitting undue weight to be given to examination results. The recently introduced demand for course work in examinations for external degrees in engineering in the University of London is a step in the right direction.

ACADEMIC FREEDOM

It may not be out of place to say a word about academic freedom. An engineering course is usually a full-time course—lectures, tutorials, laboratories, and drawing offices, fill 5 days per week without gaps; while the best part of 5 evenings will be needed for writing-up notes and reports and for reading. Allowing reasonable time for athletics and O.T.C. work, it is clear that there is not much leisure left for other student activities, beyond such items as the Students' Section of The Institution. For serious engineering courses, academic freedom becomes rather an academic term.

Frequently college is regarded as a place where character is formed. This is open to question. Home and school are the places where the foundations are likely to be laid. The influences at college are not necessarily better than elsewhere. A professor's character, however worthy, and his intellect, however exalted, may not excite a student's admiration. When, therefore, colleges

are criticized on the matter of character formation, it should first be discovered what it is possible for colleges to do, and then inquire what is being done. The cultivation of good habits and the setting of good example may be expected; but to suppose that the staff can make a student truthful just because he is probing into Nature's truths is asking too much.

In disciplinary matters, surely a college should be held responsible for carrying out its duties and spending properly the money received from grants, benefactions, and fees. To permit truancy, laziness, untidiness, insolence, etc., amounts to dereliction of duty on the part of the staff. Insistence on regimental obedience to laboratory regulations is not interference with academic freedom, but rather fulfilment of Home Office safety requirements.

If the foregoing views appear to regard universities and colleges as centres of training for the professions and professional institutions rather than as centres of culture and learning, is not this the case in actual fact? And were not universities founded for educating practitioners in theology, law, and medicine, rather than for providing a liberal education?

A CENTRAL OR NATIONAL INSTITUTION FOR RESEARCH AND SPECIALIZED TEACHING

Obviously there is a need for a national college where only advanced, post-graduate, and specialized work, would be done. Students and workers would be recruited from all parts of the kingdom. As these would be selected for their ability to continue higher studies or carry out original investigations, their services would be properly conserved for the community. Their outlet would be research institutions, the National Physical Laboratory, the Post Office, and works requiring such assistants. In many ways the Imperial College of Science and Technology would meet such requirements, but for the proper carrying out of these ideals, undergraduate work would (except perhaps in the advanced stages) be left to the technical institutions. The professoriate would consist of a large body of specialists. Compared with the total number of students trained for engineering degrees and diplomas, the number of such highly-trained individuals would be comparatively small.

TEACHERS

The teaching of engineering is best done by those who have had professional or practical experience as engineers. Although it is necessarily engineering science rather than engineering practice that has to be taught, the teacher should, nevertheless, be conversant with the latter, otherwise the commercial side may be overlooked. Teachers of the schoolmaster or research type can scarcely be expected to train men successfully for a livelihood which depends on economics for success. Unless, therefore, a teacher has been through the works and earned his living in practice there may be a lack of reality in his work.

The kind of instruction needed is to teach students to use drawings, but not to train draughtsmen; to teach students how machines are designed, not how to design them. Draughtsmen and designers are trained in the works. The illustrative problems and exercises should be based on practice, but the memory should not be loaded with a mass of practical details and empirical data. Properly taught, engineering principles develop reasoning powers.

After 60, one's value as a teacher may be open to question. To enable teachers to stop teaching (not working), their superannuation scheme should permit them to retire at 60 on half pay.

PART-TIME COURSES—NATIONAL CERTIFICATES

For many years it has been the practice to award certificates on the successful completion of regular courses, but a revolutionary change occurred when National Certificates began to be issued by professional Institutions in collaboration with the Board of Education and later with the Scottish Education Department. Equally profound was the effect when professional Institutions, including The Institution of Electrical Engineers, accorded recognition (in whole or in part) to National Certificates as educational qualifications for Institution purposes. The remarkable success of this scheme is well illustrated in the graphs shown in Figs. 1–3.

A word of warning may here be given to those who affect to despise degrees, diplomas, certificates, etc. Students who neglect to obtain official or recognized evidence of their educational attainments do so at their own peril. Experience proves that the disadvantages associated with following a prescribed course are negligible compared with the advantages.

It can probably be stated without contradiction that nothing has done so much to advance part-time education in Great Britain as the institution of National Certificates, even if much of their value has to be attributed to the recognition given them by professional Institutions. A brief description of the certificate schemes in electrical engineering may not be out of place. Joint committees composed of 6 persons in England and of 8 persons in Scotland (one-half H.M. Inspectors and one-half I.E.E. representatives) conduct the schemes. Schools and institutions desiring recognition submit courses for approval. Uniformity is not aimed at, but the scope and standard of the work must reach a satisfactory minimum. Thus no school sacrifices its individuality. Assessors are appointed for the several subjects by The Institution, and these assessors are responsible for ensuring satisfactory examination papers, and for fair marking of the scripts. Their powers are wide, and they may further call for laboratory and homework notebooks. A certain standard is required for "Pass," while "Distinction" is awarded where merited. The main duties of the joint committees are to consider applications from colleges for the approval of courses and to determine the results. For recognition of a National Certificate by our Institution, the present regulations demand a "Credit" in each of two electrical papers—the "Credit" being a higher standard than the "Pass."

The National Certificate has two grades—the Ordinary, taken after a 3-years' part-time course, and the Higher, taken after a further 2-years' part-time course. Passed with "Credits," these are accepted respectively in lieu of Part I except "English" and Part II of the Institution examination.

The result of the advent of National Certificates may be

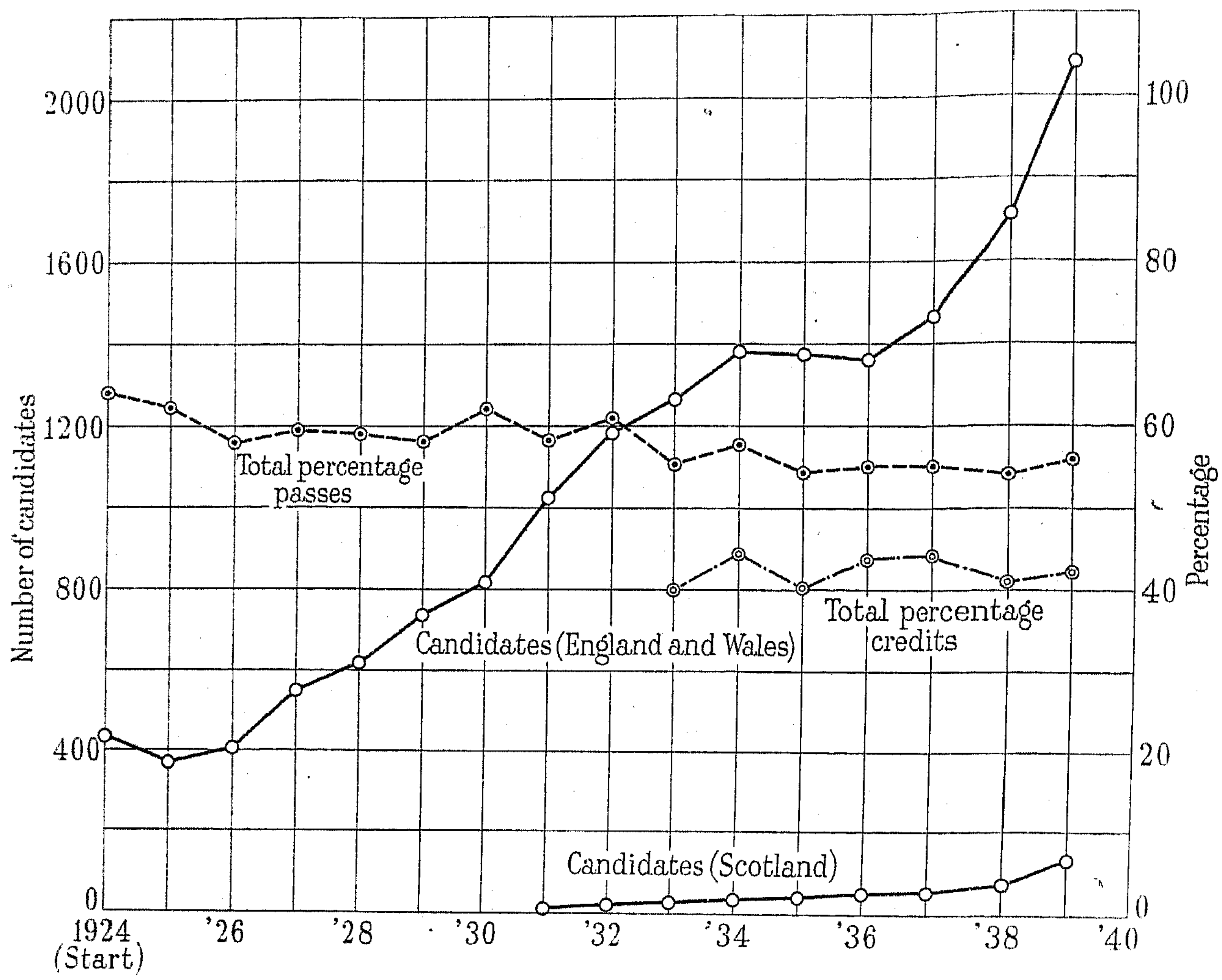

Fig. 1.—Ordinary National Certificates in Electrical Engineering.

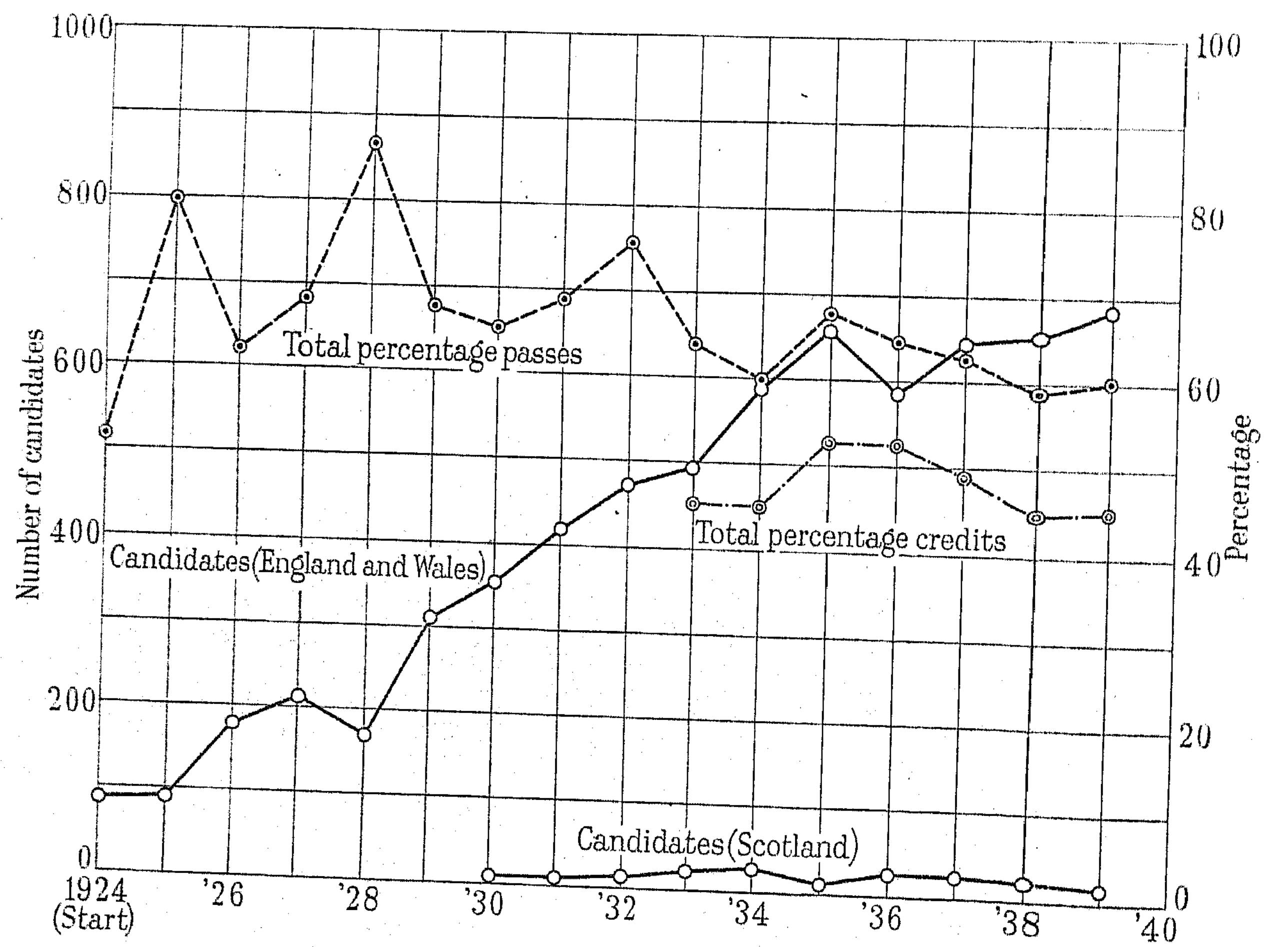

Fig. 2.—Higher National Certificates in Electrical Engineering.

summed up as follows: The part-time student can now obtain a certificate of his educational attainments recognized throughout the country and by his professional Institution. The professional Institutions have, as a consequence of the National Certificate Scheme, been brought into direct contact with those students receiving part-time instruction. All concerned with the work of the schools will testify that, despite the extra outlay entailed by the requirements of the scheme, the work of the educational authorities and of the Board of Education has been much facilitated. Mostly, however, teaching has benefited. Of necessity, some of the part-time teachers have limited experience in teaching. The helpful work of the assessors in connection with the setting of the papers and the marking of the scripts has encouraged teachers to reach the present high standard.

A modern National Certificate scheme is given in an Appendix.

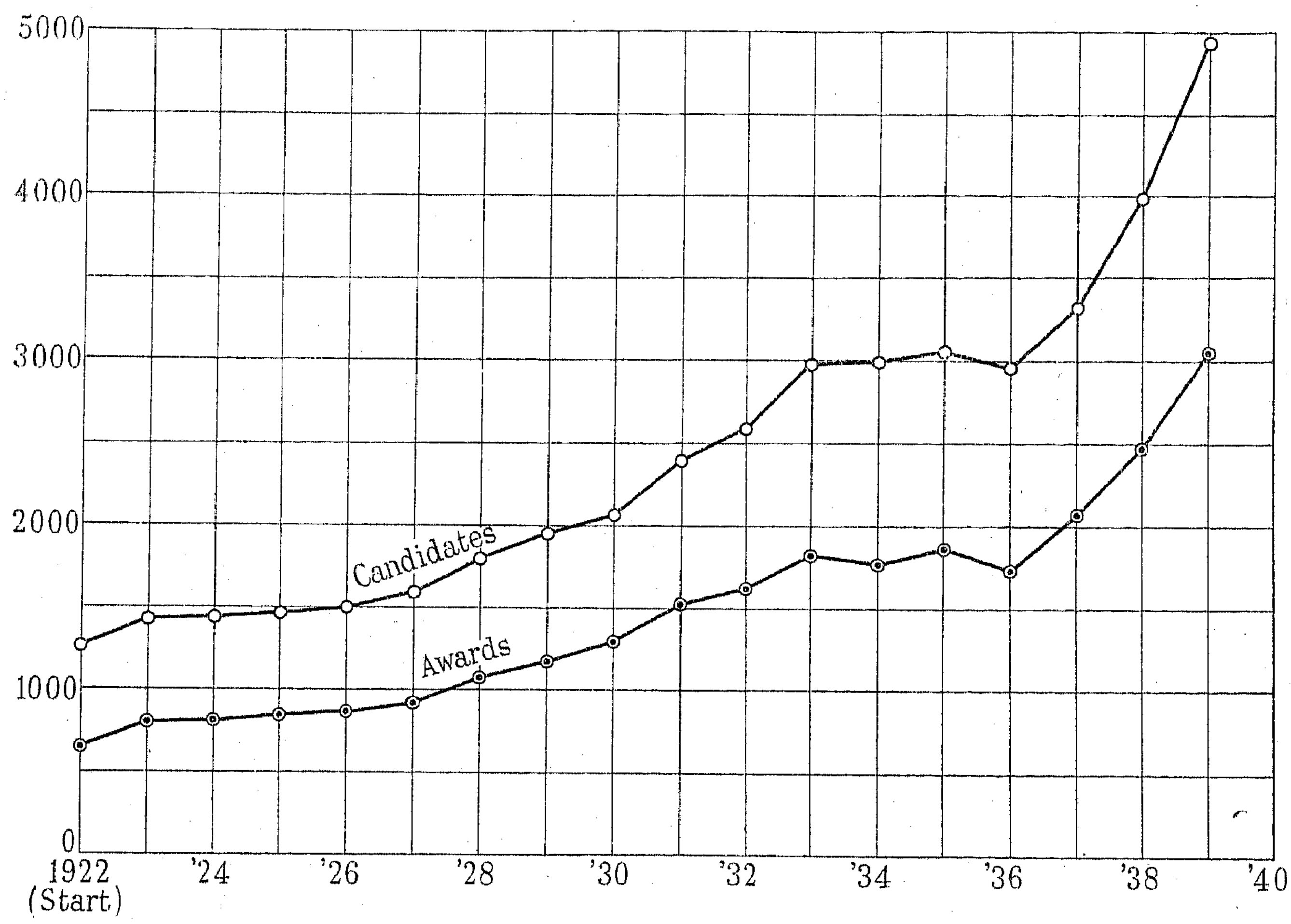

Fig. 3.—Ordinary and Higher National Certificates and Diplomas in Mechanical Engineering—England and Wales.

LINK BETWEEN PART- AND FULL-TIME COURSES

The Institution does its part in encouraging all suitable candidates, and recruits about one-third from part-time courses. This fact alone shows what a fruitful supply of good engineers are found in evening classes. If we dig deeper we shall perhaps see where the educational authorities might advance a stage. It may be stated that the bulk of both full- and part-time students come from the working and lower middle classes. Ignoring the day student who pays his own fees—who in any case seems to be a decreasing rarity—and confining ourselves to students of limited means, we find that some of them come into full-time courses with the aid of scholarships and grants obtained frequently in an adventitious manner (scarcity of candidates, helpful headmasters, shrewd parents, etc.), while others go to night school—so the chances are that, of two equally good men, one becomes an engineer easily, via a Degree, and the other arduously, via a National Certificate. Despite these fortuitous circumstances, it is possible to straighten out matters somewhat. For a long time the Royal Technical College, Glasgow, has known that students who worked their way from evening to day classes almost invariably did well; whereas day students sent by their parents were of all kinds. A benefaction enabled the College to award bursaries to assist in the transfer from evening to day classes, and the result has been wholly good. This is not surprising. The candidate for transfer has proved his ability by his record, which usually includes a Higher or an Ordinary National Certificate, and invariably many high Passes. According to circumstances, such men are awarded bursaries for 1, 2, or 3 years (amounts up to £100, £75, and £50 per annum respectively), to obtain the college diploma, while they frequently take also the external B.Sc. Degree of London. So far as electrical engineering is concerned, such students seldom return to their former employment, though the placing of them is not always so easy as with students who have yet to serve an apprenticeship. Such transferred students may have to make sacrifices; but the risk for either college or student is practically nil. It is suggested that here is a way in which educational authorities might help further the engineering profession.

SCHOLARSHIPS, BURSARIES, GRANTS, ETC.

This is a difficult subject. An award to a part-time man of proved capacity with correctly-chosen career is

safe compared with an award to a promising schoolboy. The boy wins a scholarship or the headmaster has ample reason to recommend him for a grant, but who knows how the boy will develop. Was he precocious? Are school subjects within and college subjects without his grasp? Is he clever but lazy? A great gamble and often no one to blame when failures occur. The safest remedy for failures is to withdraw the grant, etc., in time—and in this there is no disgrace, for who can foretell the result of an experiment? If a boy has chosen the wrong career the error should be rectified as soon as possible—wisdom must not be expected from an immature mind.

Scholarships to graduates and undergraduates differ from entrance scholarships. College evidence is available. Competitive examinations are seldom needed, and nominations usually suffice. Such nominations are made not only on the results of college examinations, but largely from personal knowledge. A few illustrations may be given. Much useful and original work has been done by the Royal Commissioners for the Exhibition of 1851. From the profits of this great peace effort on the part of the Prince Consort, the Commissioners not only bought the land on which the colleges and museums in South Kensington are built, but by means of bursaries and scholarships they enabled graduates from all parts of the Empire to undertake research work in science in other universities at home and abroad; after setting this example they developed a scheme of bursaries to enable graduate apprentices to obtain an income on which they could live.

A comparatively recent institution owes its existence to the munificence of the late Sir James Caird of Dundee. Every year the trustees of this fund make awards to necessitous and meritorious undergraduates and graduates in various branches of learning, including electrical engineering. The scheme is conceived on broad lines; it enables promising boys to go to college, evening students to transfer to day classes, and graduates to complete their apprenticeship, while senior men are enabled to travel to other universities, works, etc. In this connection too, mention may be made of a useful scheme adopted by the Royal Technical College, Glasgow, a few years ago. In the amended constitution, authority was obtained for paying into a pool called a "residue fund" odd sums of money, certain unallocated scholarships, residues, etc. Though the annual amount may not be large, the fund has proved of great service. Despite the great number of existing scholarships, bursaries and grants, every professor knows of individual cases of hardship where a small grant may do much good. A change in family circumstances, an ex-apprentice finding the costs of a college career beyond his means, or one of the thousand other unforeseen events, may make it hard for a student to continue to work on satisfactorily. It should be remembered that a large percentage of those who benefit by a college training are not geniuses, and that comparatively few men of high scholarship standard are needed in engineering; hence every effort should be made to encourage those who later will help to form the backbone of engineering.

PRACTICAL TRAINING

Fortune has favoured the electrical engineer in many ways. The development of the industry coincided with the development of technical education, while electrical engineering was more dependent on technical knowledge than almost any other industry. These fortunate coincidences resulted in a new industry almost free from the traditional pupilages and apprenticeships of the older branches of engineering. Premiums became the exception rather than the rule, and the large electrical firms rapidly adapted themselves to the new requirements. As a result, technical education was encouraged both in universities and technical colleges; while the outlet grew so rapidly that the demand often exceeded the supply. The growth of The Institution is an indication of the rapid rise of the industry.

Credit must be given to the large firms which early recognized the situation and met it. Obviously a graduate, aged about 20 to 22, was not in the same category as a 16-year-old boy with no technical training. Thus the 5-year apprenticeship offered to the latter was replaced by a 2- or 3-year apprenticeship. Moreover, the shorter course was adapted to the needs of engineers-in-training —short periods in several departments. Lastly, the college or engineering apprentice was offered a living wage. As an adjunct, firms permitted students to come for short spells during long vacations. These admirable arrangements had many advantages; on the part of the firm, the vacation period served as a useful probationary term previous to an apprenticeship, while the latter enabled the firm to try out a man before offering him an assistantship; on the students' side there was the advantage of trying out different classes of work (e.g. "heavy" and "light") and different employers, during vacations, so that he did not enter on a career blindly. It is unlikely that the old 5-year apprenticeship course will continue for electrical engineers unless the practical time is included in some sandwich system; also it is likely that all graduates will be offered a living wage as soon as they leave college.

WHEN TO GO TO COLLEGE

This affects mainly day students. On this matter opinions vary widely. The one given here may not be popular among engineers, but at least it has the merit of being based on experience. Careful records extending over many years show that students do best who go straight to college from school. Most firms who prefer youths to start their apprenticeship before entering college nevertheless seem loth to accept first-year students for vacation experience—a contradiction not easy to explain. Of course in some areas, e.g. Glasgow, the facilities for an apprenticeship in electrical engineering are so limited that there is a natural tendency for students to pass straight from school to college—contrary to the practice with mechanical engineers. One point should be emphasized, however; whenever there is an interval between school and college, the student should attend evening classes regularly and, whatever technical subjects he takes, he should not let his knowledge of mathematics and science lapse—otherwise his first year at college may be a dismal failure. A better and safer plan, however, is for the student to go to college straight from school; and this is advised, wherever practicable. As for the promising evening student, he should, wherever possible and desirable, be helped to transfer to day courses. Whatever procedure may be best for other branches of engineering,

the one developed in recent years which enables students to gain practical experience during vacations before embarking on a post-graduate apprenticeship is probably best suited to electrical engineers. By avoiding a break between school and college, the pursuit of learning is not interfered with—a valuable asset from an economic standpoint. The probationary vacational periods spent in works give the youth a chance to explore different branches of electrical work, and give him a sufficient touch of practice to excite his keenness. The firms can compensate their loss in training these immature youths by avoiding later loss arising from unsuitable selection. Lastly, the post-graduate apprentice with a living wage is a very different member of the community from the traditional apprentice.

ADVICE TO SCHOOLBOYS

The choice of a career is not easy. Chance is an unsafe guide, while a boy's immature mind may mislead him. Colleges can aid careers councils in many ways, tutors and professors can advise, visits can be encouraged, etc. For several years the Royal Technical College has arranged a visits week in June for the schools. The secondary schools send large classes with their masters. In this way a large number of small groups of boys (and girls) are shown over the departments, see interesting experiments, and hear short lecture-demonstrations.

APPENDIX

(*MS. received 2nd November*, 1939.)

A Modern National Certificate Course

From time to time discussions have been held concerning the desirability of common courses for mechanical and electrical engineering, either up to and including the third (S.3) year of the Ordinary Grade Certificate or for the first and second (S.1 and S.2) years only. These discussions have been helpful in many ways, and although there seems to be little likelihood of a common S.3 year, the scheme set forth below shows that a common course for the first two years is possible without undue compromise.

Apart from conveniences in teaching in part-time institutions, the great advantage of a common course for the S.1 and S.2 years is the possibility of a candidate obtaining a double Ordinary Certificate in four years. For many students the Higher Grade Certificate is neither feasible nor desirable, but to such the possession of the Ordinary Grade Certificate in both mechanical and electrical engineering may be a great asset.

The courses shown in the Table were drawn up in 1939 by the Royal Technical College, as the Central Institution in collaboration with the affiliated centres in the West of Scotland. (This co-operation is effected by means of a Joint Committee through an Organizer.)

SCHEME OF COURSES FOR ORDINARY AND HIGHER GRADE CERTIFICATES

Ordinary Grade

<table>
<tr><th>Course</th><th colspan="2">Electrical Engineering</th><th colspan="2">Mechanical Engineering</th></tr>
<tr><td rowspan="3">S.1</td><td colspan="2">Mathematics</td><td colspan="2">2 hrs.</td></tr>
<tr><td colspan="2">Mechanical science</td><td colspan="2">$2\frac{1}{2}$,,</td></tr>
<tr><td colspan="2">Engineering drawing</td><td colspan="2">$2\frac{1}{2}$,,</td></tr>
<tr><td rowspan="3">S.2</td><td colspan="2">Mathematics</td><td colspan="2">2 hrs.</td></tr>
<tr><td colspan="2">Electrical science</td><td colspan="2">$2\frac{1}{2}$,,</td></tr>
<tr><td colspan="2">Engineering drawing</td><td colspan="2">$2\frac{1}{2}$,,</td></tr>
<tr><td rowspan="4">S.3</td><td>Mathematics</td><td>$1\frac{1}{4}$ hrs.</td><td>Mathematics</td><td>$1\frac{1}{4}$ hrs</td></tr>
<tr><td>Mechanics</td><td>$1\frac{1}{4}$,,</td><td>Mechanics</td><td>$1\frac{1}{4}$,,</td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>Applied mechanics</td><td>$2\frac{1}{2}$,,</td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>Heat engines</td><td>3 ,,</td></tr>
</table>

Higher Grade

<table>
<tr><td rowspan="3">A.1</td><td>Mathematics</td><td>$2\frac{1}{4}$ hrs.</td><td>Mathematics</td><td>$2\frac{1}{4}$ hrs.</td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>Strength of materials and general design</td><td>$2\frac{1}{4}$,,</td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>Electrical engineering</td><td>3 ,,</td></tr>
<tr><td rowspan="7">A.2</td><td>Mathematics</td><td>$2\frac{1}{4}$ hrs.</td><td>Theory of machines and machine design</td><td>$2\frac{1}{2}$ hrs.</td></tr>
<tr><td>or</td><td></td><td>Heat engines</td><td>3 ,,</td></tr>
<tr><td>Heat engines (S.3)</td><td>3 ,,</td><td>Mechanics of fluids</td><td>$2\frac{1}{2}$,,</td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>or</td><td></td></tr>
<tr><td>Electrical engineering</td><td>$2\frac{1}{2}$,,</td><td>Aeronautics</td><td>2 ,,</td></tr>
<tr><td></td><td></td><td>or</td><td></td></tr>
<tr><td></td><td></td><td>Workshop technology</td><td>2 ,,</td></tr>
</table>

By following uniform schemes of work, the students can transfer to different schools within the area; while a common examination paper becomes feasible.

In arranging the curriculum for three evenings per week, it was desired to avoid two lecture periods on the same subject on the same evening. For this purpose tutorial classes and course work were introduced wherever possible; for example a mathematics lecture would be followed by class exercises, or a lecture in electricity and magnetism would be followed by a laboratory class. The sub-division would have been carried further but for teaching difficulties in small centres. To overcome such difficulties, heat and mechanics in S.1 were combined in mechanical science, while mechanics was excluded from S.2. Such compromises were required in order to produce a common scheme suitable for all centres in the area, as well as for the two main branches of engineering. In S.3 there will be three assessed papers, mathematics and mechanics forming a single paper common to both branches.

Another feature which the framers of the scheme had in mind was the transference of promising students from the part-time certificate classes to the full-time diploma classes of the Royal Technical College. This diploma is awarded after the satisfactory completion of a three-years' course, for which the admission examination in future is to be slightly inferior to that of the degree and will include English as a subject. The diploma thus satisfies the educational requirements of The Institution. With satisfactory completion of the S.2 year and the paper in English, a student can enter the diploma course; while with the Ordinary Grade Certificate he can enter the second year of his respective branch of the diploma course—thus the transfer from part-time to full-time courses is simple.

In drawing up the courses for the Higher National Certificate, options were introduced wherever feasible. By a suitable choice of such options in the mechanical engineering course, a student could satisfy the requirements of aeronautical, production and other branches.

SOUTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By HENRY JOSEPH, Member.

"ELECTRICITY AND CIVILIZATION"

(*Address received* 29*th September*, 1939.)

When, some 2½ years ago, your Committee did me the honour of selecting me as a Vice-Chairman, leading, in the natural course, to my present office, it occurred to me to select, as the subject of my address, "Electricity and Civilization." While I have adhered to this selection, I have at times doubted whether civilization itself would survive the intervening period. Fortunately, however, I am still at liberty to talk of something which continues to exist, and I am sufficiently optimistic to believe that its existence will continue in spite of present-day threats.

Electricity, which is inextricably interwoven with all the activities of mankind, is usually described as man's greatest civilizing influence. Since practically none of our activities to-day are possible without its aid, we say that it is an essential attribute to the progress of civilization.

We find in the proceedings of this Institution a desire to develop and extend our knowledge of electricity, and of its practical applications, at an increasing rate of acceleration. It seems as though our very existence depended on finding out in the least possible time all that is to be known about it, and all the things that are to be done with its aid. Let us therefore pause, and allow our thoughts to wander a little to see whether we can find out what we aim to accomplish, and in what direction all this activity is leading.

Since electricity is admittedly the greatest agent of civilization, let us first consider what we mean by civilization itself. There is no single word or sentence which can adequately define what we mean by the word. It includes the whole political, social, economic, intellectual, and moral development of humanity. The fundamental ideas contained in the word are progress and development; the improvement of civil life, the development of society, of the relations of men towards each other; the increasing production of sources of wealth and of well-being amongst a population; and a more equitable distribution of these; the development of individual life, of man himself, of his faculties, sentiments, ideas. Also their simultaneousness, their close and swift union, their action on one another.

This lengthy definition is based on Decoudray, and was written about 100 years ago. I can find nothing in it that is less true to-day than it was then. I invite you to consider how electricity plays its part in every sentence, nay in every word, in this description.

Now, while we must admit that all inventions, like everything else, are in the present state of man's development subject to abuse, yet it cannot be denied that civilization as it has just been defined is in all its aspects desirable. Hence the extended use of electricity as an essential aid to development is desirable also.

A BRIEF HISTORY OF CIVILIZATION

Let us very briefly run over the history of civilization, in order to see what has happened in the past, so that we may be better able to judge what is likely to happen in the future.

First, before the dawn of civilization, we must take account of the earliest signs of human intelligence, when man fashioned rude implements out of stone to protect himself against wild animals and against other men. Later he learned to use bronze, and then iron.

During all these very long periods, there was a tendency for primitive men to bind themselves together as families and clans, for mutual protection.

If anything like a definite time can be stated as the dawn of civilization, it was some 6 000 years ago—a very short period compared with the life of man on earth—when the Memphian Monarchy was set up in Egypt and the Pyramids are supposed to have been built.

This period extended from the 40th to the 20th century before the Christian era, and takes in the dawn of the Brahman religion in India. In the 20th century B.C. we come to the period of Babylon and Nineveh in Assyria, and of Abraham and the Patriarchs.

Here we have a definite civilization—the movement of bodies of men under their own leaders to more fertile lands, and the inevitable fighting between rival tribes for the possession of more attractive territory.

In the next two centuries we see the Theban Empire of Egypt, the erection of the monuments of Thebes, the Ninevite Empire in Assyria, Moses and the teaching of religion, the Phoenician Colonies, the Iraneans, and the rise of Zoroaster and of Hindoo civilization in India. So we go on till we reach the 7th century B.C., to which history with definite and reliable dates can be traced.

Civilization reaches a higher level in the 6th century B.C., with the establishment of the Babylonian Empire and the Persian Kingdom.

Thus, by gradual steps, we are brought down to the Christian Era, and the simultaneous growth of civilization in Europe.

Civilization, in the early stages to which I have referred, manifested itself in building, art, and the making of weapons of war, and in government by kings and emperors, the making of laws, and the regulation of the lives of the people.

Building and art rose to quite reasonable heights, limited only by the absence of power. Levers and wedges, with the free use of slave labour, were used to

raise heavy blocks of stone and to place them in position. But all this progress was very slow.

The Chaldeans originated the art of writing, the building of cities, the institution of a religious system, and the cultivation of science and mathematics, particularly the science of astronomy. They were skilled in agriculture and manual handicrafts, weaving and dyeing, embroidery, and the making of carpets, chairs, and tables, handsomely decorated glass and enamels, bricks, porcelain and jewellery. In engraving, they were not much behind the present standard. Literature, poetry, and music, were also introduced.

Similar progress seems to have been made in China, during the same period, in arts, science, and handicrafts; but I have been unable to find any confirmation of the belief held by some people that China was able to boast an earlier and higher grade of civilization than was reached in Asia Minor and Europe.

Everything seems to indicate that, in all directions in which exact knowledge is not essential, civilization reached fairly high levels in the early stages of its history. But development has for the most part been gradual and evolutionary. If civilization has shown since its birth a gradual and steady growth, it must be admitted that in certain directions this growth has been followed by a decline. I refer in particular to the decorative arts, which undoubtedly reached very high levels in the time of the Chaldeans, and again in ancient Greece. I venture to say that the present century has seen a definite decline in art, music and literature. Manual dexterity also shows a downward tendency, owing to the introduction of machinery and the craze for cheap mass-produced products. On the whole, however, averaging one type of human activity with another, one may reasonably describe the progress of civilization since its dawn as one of slow but steady advance. In spite of the slowness of this growth, it has probably followed a rising curve, for each step of progress has been accomplished in a shorter period than the one before it. From various observations it has been established that millions of years must have elapsed before man reached the stage at which civilization can reasonably be said to have begun to assert itself.

THE MECHANICAL AGE

Since then, a comparatively short period of some 6 000 years brings us to the present day. I hope to show that out of this short span a trifling one of 100–150 years has been occupied in developing the present mechanical age. No definite date can be given as the beginning of this era. Each invention is a development following on another, but two major ones may be said to have formed the foundations of this age, namely the steam engine and electricity. Although the former dates back to Hero of Alexandra in 120 B.C., and primitive steam toys made by Branca in 1629, it was not until the end of the 17th century that a genuine engine with cylinder and piston was made. But it was during the latter part of the 18th century, at the hands of James Watt, that the steam engine became a practical source of motive power, and from that period the modern mechanical age can be said to date.

A similar story can be told of the development of electricity. The fact that amber, when rubbed, acquires the property of attracting light particles of matter was known to the early Greek philosophers, such as Thales of Miletus, in 600 B.C. In fact, the word "electricity" is derived from the Greek word for amber. It was not, however, until A.D. 1600 that Dr. Gilbert coined the word in his work "De Magnete," in which he pointed out, *inter alia*, that electricity can be of two kinds, "vitreous" and "resinous"—or, as we now call them, "positive" and "negative."

Galvani's experiments with frogs were published only 148 years ago. The first attempt at a primary battery was when Volta published his description of the Voltaic Pile in 1800.

It was only 100 years ago that Sir Humphry Davy invented the arc lamp, which may fairly be regarded as marking the beginning of the commercial use of electricity. But even a shorter space of time, during the lifetime of some of us here, may be taken as the period during which electricity has been distributed as a commercial commodity for the use of all and sundry for any purpose for which it might be required.

Even during my own membership of this Institution, a period of just over 40 years, electricity has made such strides that it is almost impossible to realize that so short a time has been occupied in such a phenomenal development.

GENERATION

Forty years ago, generating sets of a few hundred kilowatts capacity were installed in some of the larger stations. Now 30 000-kVA units are common, and 50 000-kVA units in base-load stations, while 100 000-, 150 000-, and even 200 000-kVA sets have been installed.

Forty years ago, boiler pressures were in the region of 120 lb./sq. in., and 15 years later they reached 200–250 lb./sq. in. with 600–650° F. superheat. Now we have pressures of 1 400 lb./sq. in. with 1 000° F. superheat. With Loeffler plants, 2 000 lb./sq. in. at 940° F. superheat have been attained.

Forty years ago, boiler drums were some ½ in. thick; to-day a figure of 5 in. is not unknown.

Even so, these high pressures and large drums are only possible owing to the great advance made in the manufacture of special steels, nickel-chrome-molybdenum alloy being used for the purpose. This is only one of many thousands of instances in which development in one branch of applied science has facilitated progress in another.

In the United States the cooling of alternators by means of hydrogen, with resultant lower windage losses and greater cooling properties, as well as smaller cooling equipment, has been a contributory factor in the building of these very large alternators. Fabricated methods of construction in this country and elsewhere are among the collateral developments without which these large sets could hardly have been possible.

Voltages during the period in question have risen from some 10 kV to 132 kV in this country, and even higher elsewhere.

Forty years ago, water-tube boilers with chain-grate stokers were nearly universal in central stations. During the intervening period the introduction and development of the powdered-fuel system has made great strides, and its use has spread beyond the power station to manu-

facturers' works furnaces. With it has become also the complete electrical control of boiler plant, and the abolition of coal from the boiler-house floor.

It is perhaps a natural development in this all-electric age that the flow of fuel, air, and water, into the boilers, the control of temperature, pressure, and the percentage of CO_2 in the flue gases, as well as many other operations, should be electrically controlled from a switchboard remote from the actual boilers. The whole system of steam generation has been modified by the introduction of steam bleeding, successive stages of intermediate heaters, water walls, and so forth. And at the finish all we can boast at the best is an overall thermal efficiency of 30 %, or from coal to consumer of even less. Surely there is still great scope for future development.

THE GRID

Perhaps one of the most remarkable of modern developments in electricity supply is the grid system, by which a comparatively small number of large selected power stations are coupled together so that—in theory—if any one station is shut down the others automatically take up its load. I look forward with some hope, but not with complete confidence, to such a consummation being effective in fact.

We have apparently arrived at a critical phase in the development of electricity supply when the generation of power has grown beyond our means of controlling it. Forty years ago, the switching of comparatively small quantities of power concentrated in one power station involved nothing more serious than the burnt contacts of an air-break circuit-breaker. Now, with the enormous reservoir of energy behind it, a short-circuit often leads to disastrous consequences when failure of the switch to open the circuit results in the destruction of the breaker and the shutting-down of the supply over a large area.

To make matters worse, the element of fire is introduced by the presence of large quantities of inflammable oil. This causes the supply engineer to ask for switchgear capable of withstanding heavier and heavier rushes of current. A few years ago, rupturing capacities of 100 000 and 150 000 kVA were considered ample. Now figures of 250 000, 350 000, and even 1 000 000 kVA are not going to be too much to ask for.

Plants have been put down in makers' works to test switchgear under these severe conditions, and there seems to be a race between the supply engineer, on the one hand, in increasing his liabilities; and the switchgear manufacturer, on the other hand, in attempting to meet them. I am afraid that, long before these plants can have earned enough money to have paid for themselves, they will have become obsolete. It is in the direction of h.v. switchgear, more than in any other, if the grid system is to be maintained, that electricity supply looks for some radical departure in principle. To the impartial observer it seems somewhat crude in these scientific days to attempt to interrupt such circuits merely by the separation of conductors. Here is an avenue for most valuable research—to devise some method by which the circuit is opened when the current or voltage is at zero; possibly by electrical as well as by mechanical means. To limit the value of the short-circuit current, reactors are inserted. But a multiplication of these leads to excessive voltage-drop at heavy loads.

If we *must* use some medium in our switches to extinguish the arc, cannot we find something better than highly inflammable oil for the purpose? Efforts are, of course, already being made in these directions, but I venture to suggest that the ultimate solution will lie in a radical departure from present-day principles.

UTILIZATION OF ELECTRICITY

On the consumer's side, during the period under review, developments have been made in so many directions that it is impossible to refer to them all in this Address. I propose, therefore, to limit my remarks to a few of particular interest. In all of these the consumer obtains the service that he seeks in the course of the conversion of electrical energy into energy of some other kind. These may be divided under five heads: Mechanical energy, chemical energy, sound, light, and heat.

Mechanical Energy

The electric motor in its various forms is the basis of almost countless developments, from the driving of factories to the working of an electric railway. Unfortunately, it is no longer economical to supply direct current for many of these purposes, although it is very much more flexible than alternating current where any great variation of speed is required. Variable-speed alternating-current motors of various kinds are available, but unfortunately their cost is at present too high for their more general adoption. Alternating current also has the great disadvantage that the current wave lags behind the voltage, and so introduces the necessity of power-factor correction, the onus of which is put upon the consumer.

Is it too much to hope that the future will enable engineers to supply on equally economical terms the finished product of direct current, instead of alternating current which we may regard as the raw material?

Chemical Energy

One of the oldest electrochemical developments is electro-plating, of which the most recent involves the use of the rare metals cadmium, rhodium, and chromium. Chromium-plating—in itself a fairly modern development—is now being carried out on a very large scale. A modern high-speed chromium-plating equipment may consist of a series of some 15 vats, totalling 120 ft. or more in length. The articles, carried by a conveyor system, pass through various cleaning processes before and after the preliminary nickel-plating, on top of which the chromium-plating is deposited. The current is supplied from large banks of rectifiers, and nickel-plating vats are often fitted with electric heating elements immersed in the electrolyte.

Within the last decade, largely through the extended use of aluminium alloys for aeroplanes, the process of anodization or anodic oxidation has been developed. It is well-known that aluminium oxidizes on exposure to the atmosphere. This oxide is of a powdery nature, and, while it affords some protection from further action, it becomes detached, and thus leaves the metal exposed

to further attack. The discovery of anodic oxidation for resistance to corrosion was a development of work carried out on electrolytic condensers and chemical rectifiers.

Aluminium was found to possess the property of forming an oxide film when current was applied in suitable electrolyte, the aluminium article forming the anode. This film adheres firmly to the surface and has high resistance to corrosion. Large plants have been installed in various parts of the country to deal with parts of aeroplanes and other articles made of aluminium alloys.

In the accumulator we have, perhaps, the largest electrochemical development. Considerable progress has already been made in storage-battery vehicles for house-to-house delivery where short radius and frequent starting and stopping are the principal features, but we still await the invention of a cheap, light battery which can be used for vehicles intended for larger ranges and higher speeds. If ever such a battery became available, our petrol depots might be replaced by battery-charging stations, where accumulators, built up of standard units in parallel to suit small or large vehicles, could be exchanged, when discharged, for newly charged ones, thus giving a further outlet for home-produced electricity instead of imported petrol.

The electrical refining of metals is another very important electro-chemical development which is likely to lead to vastly increased use of electricity, but this subject is too large to deal with in this Address.

Sound

The conversion of electrical energy into sound suggests many interesting modern developments such as the telephone, radio and the cinematograph. So much could be said about each of these that I prefer to say nothing at all. Let me, however, mention, in passing, the electric organ, an instrument in which there are no air pipes but in which a series of rotating discs are mounted on a spindle driven by a motor at a constant speed. Each disc has on its periphery a different number of projections, which induce currents of different frequencies in adjacent coils, these currents being amplified by means of thermionic valves and actuating a loud-speaker—a truly typical development of this all-electric age.

Light

Perhaps the most interesting and rapid progress has been made in the production of light from electricity. Starting with the carbon arc and then the glowing white-hot filament of carbon in a vacuum, by gradual stages it has proceeded, viâ the Nernst lamp, the osmium lamp and the tantalum lamp, to the tungsten-filament lamp. This, again, has evolved from a series of straight filaments *in vacuo*, to the coiled filament in an atmosphere of inert gas, and finally the coiled coil. Now we have the whole series of discharge lamps which are so familiar. Starting with the carbon-filament lamp, giving about 3½ lumens per watt, we have now reached with discharge lamps a figure of 45 lumens per watt—a truly remarkable development. Now lamp manufacturers are turning their attention to the use of fluorescent powders, and we may look for further important results before long.

HEAT

Under this heading we have electric fires, cookers, and various domestic heating appliances, also electric welding and electric furnaces, all of which are rapidly replacing non-electrical methods. With the exception of the arc and the high-frequency furnace, these depend on the heating of a high-resistance wire by the passage of a current.

For the purpose of the rapid transference of heat to a domestic utensil, this method must be greatly improved before it can entirely displace non-electrical ones. Development has been along two distinct lines, transference of heat by conduction and by radiation; and improvement has been in the direction of increased loading per unit of area, made possible by metallurgical research in resistors and in better mechanical design. But, even so, there are still two difficulties to surmount. If the element is totally enclosed, and reliance is placed on the contact between the enclosing medium and the utensil, the latter has to be specially designed for the purpose; and if radiation only is depended on, so that ordinary utensils may be used, there is some risk of breakdown of the element itself. In either case an appreciable time-lag is introduced, owing to the period which must necessarily elapse before the heater reaches its final temperature. Here, therefore, lies an ample field for research with a view to striking out in a fresh direction. Burning gas reaches its maximum temperature in a second or so, and the utensil is immediately surrounded by gas at a high temperature, in intimate contact with it. Is it beyond the realm of possibility to carry out electric heating by some similar method?

DISTRIBUTION

It will be readily appreciated, with all these outlets for the use of electricity in the factory and the home, that the distribution engineer is faced to-day with some very difficult problems. Most works, except small ones, as well as flats and large public buildings, are now supplied at high voltage. With the increasing use of electricity for domestic purposes, low-voltage distribution in residential areas will soon become a thing of the past.

To cope with the very large loads which must inevitably result from the complete electrical equipment of ordinary dwellings, it will be necessary to make drastic alterations in our distribution systems. It is probable that h.v. and l.v. distributors will be laid side by side, connected at intervals by means of transformers, extra ones being inserted as loads increase. Something of the kind has already been done in certain districts.

FUTURE PROGRESS

I have dealt with the past and present. It remains now to discuss the future. I have indicated that civilization has taken a long period to reach its present level, and that the rate of progress appears to follow a rising curve. It is, however, only in recent years that records of progress have been made which can be expressed in mathematical terms.

Now all the operations involved in nature, such as the birth, growth, and decay, of living organisms, from plants, through the animal kingdom to man, are governed

by what we term "natural laws." So also the movements of the planets, the alteration in the formation of the structure of the universe and of the earth, are governed by the natural laws of physics, chemistry, and mechanics. It is not, therefore, unreasonable to suppose that the progress of civilization, together with the various elements which go towards such progress, are governed by definite mathematical laws. In order to arrive at some idea as to the nature of such laws, I have compiled various figures indicating the development of electricity supply and of a few typical modern activities and have plotted some curves. Most of these appear to follow the exponential curve fairly closely. I would say in passing that I have taken my figures from British records. I have no reason to doubt that very similar results would be shown by the records of other civilized countries.

Fig. 1 shows the growth of electricity supply in total units sold in the United Kingdom from the year 1921 to date. On this is superimposed an exponential curve drawn to the same scale. It will readily be seen how closely the units sold follow the mathematical curve.

Fig. 2 gives a similar comparison with the aggregate of maximum demands on undertakings taken over the same period. This curve tends to lag a little behind the exponential for the last couple of years, which is perhaps fortunate from some points of view. I have not been let into the secrets of the Central Electricity Board or how they anticipate the demand a few years in advance; but I have no doubt that the rapid increase in demand is not unexpected. As, however, the demands on different stations do not necessarily coincide, the outlook from the point of view of the C.E.B. is not so alarming, or from that of the plant manufacturers so hopeful, as this curve might lead one to expect.

Fig. 3 shows the growth of one of the amenities of

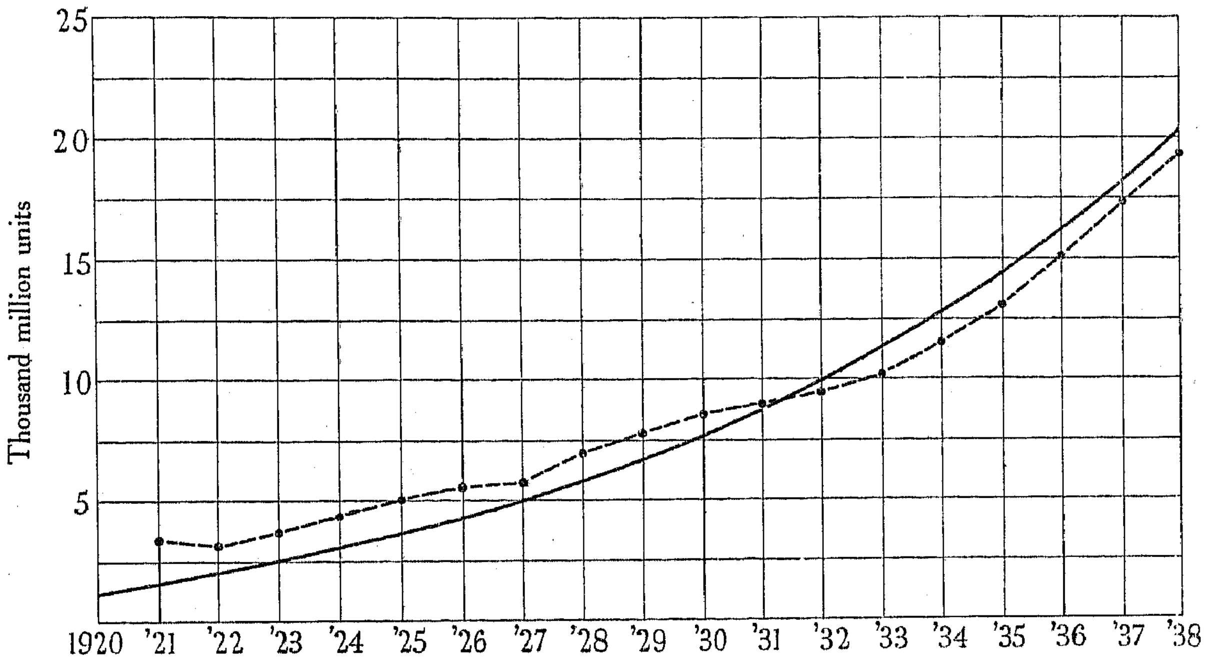

Fig. 1.—Total units sold to consumers, 1921–38.

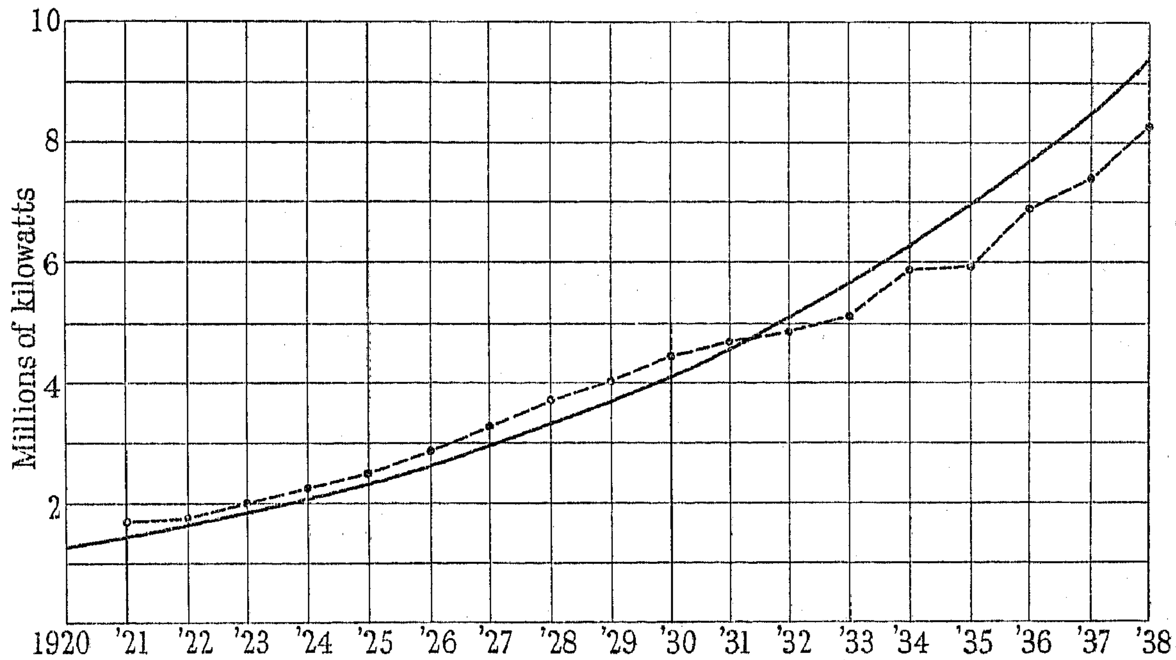

Fig. 2.—Aggregate of maximum demands on undertakings, 1921–38.

civilization as indicated by the use of motor cars. It gives the number of private cars registered in this country each year, from 1908 to date, with a corre-

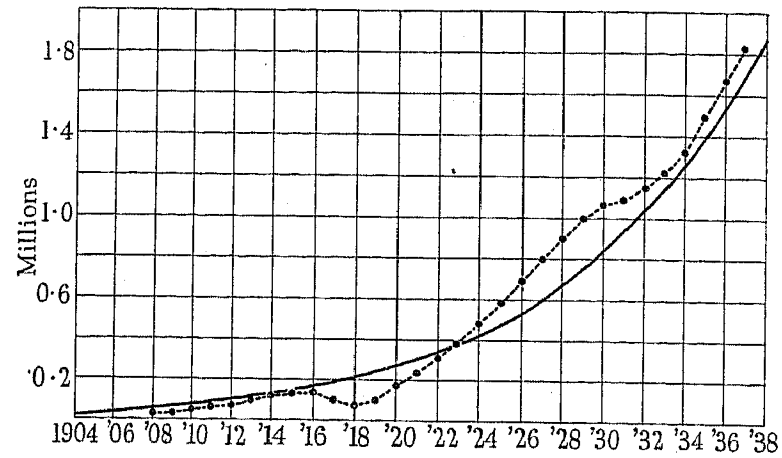

Fig. 3.—Private cars registered in the United Kingdom, 1908–37.

Airways machines, which follow fairly closely on the average the theoretical curve.

Fig. 7. I thought it might be interesting to see how membership of this Institution might look as a curve, and I have drawn this from its inception in 1871 to date. I am afraid I cannot reduce this curve to any definite mathematical basis. After all, there are so many factors controlling it which depend more on policy—a subject for controversy—than on nature, that it would be unreasonable to expect such a curve to follow any natural law. We see again the dip due to the war years; but I regret to say that since 1922 it has followed nearly a straight-line law, a state of affairs which cannot be considered to be satisfactory, in view of the much more rapid growth of everything else electrical.

If these curves represent at all fairly, as I believe they do, the progress of civilization in general and of electricity in particular, what can we hope to learn of its possible future?

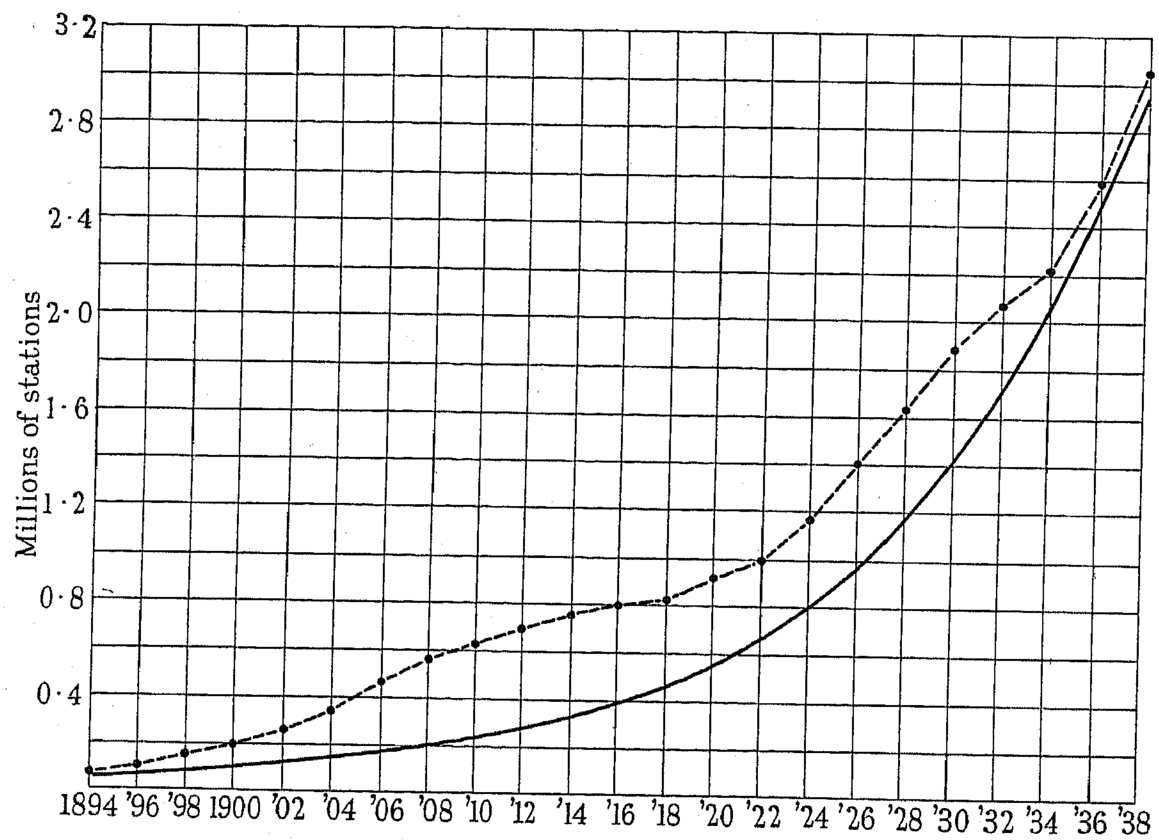

Fig. 4.—Number of telephones in the United Kingdom, 1894–1938.

sponding exponential. It is most interesting to see how closely it follows the mathematical curve. One notes the check caused by the last war, and the recovery in subsequent years, leading to the curve of progress overshooting the exponential before it settles down again to very nearly a natural rise.

Fig. 4 gives the total number of telephones installed in the United Kingdom from 1894 to date, which on the whole follows the theoretical curve fairly closely. Here again the war years caused a check, with subsequent over-recovery.

Fig. 5 shows the number of wireless licenses issued per annum from 1924. These increased at a more rapid rate than an exponential up to 1932, after which a flattening of the curve took place which is suggestive of saturation.

Fig. 6 gives the miles flown per annum by Imperial

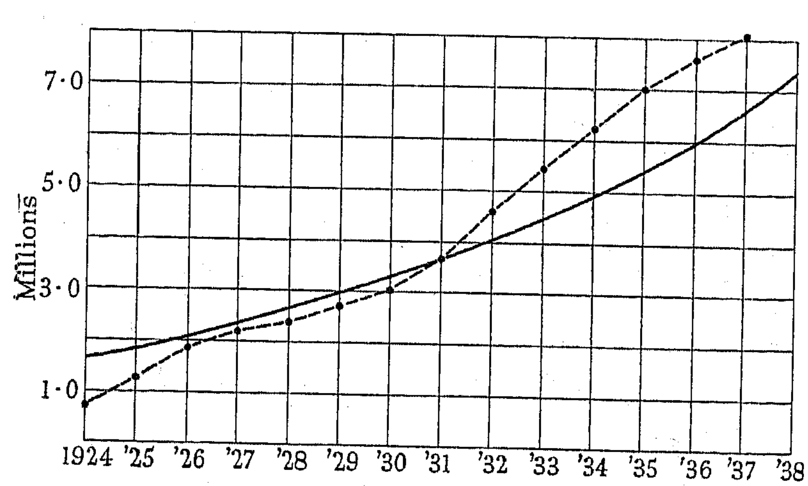

Fig 5.—Number of wireless licences, 1924–37.

Referring back to Fig. 1, since 1922 the units sold have increased by 500 per cent, and very closely follow the

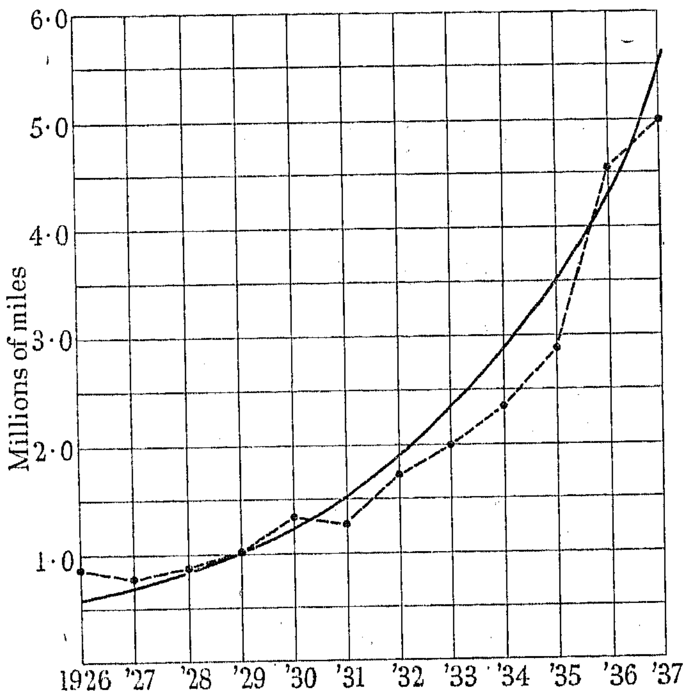

Fig. 6.—Civil aviation. Number of miles flown per annum by Imperial Airways, 1926–37.

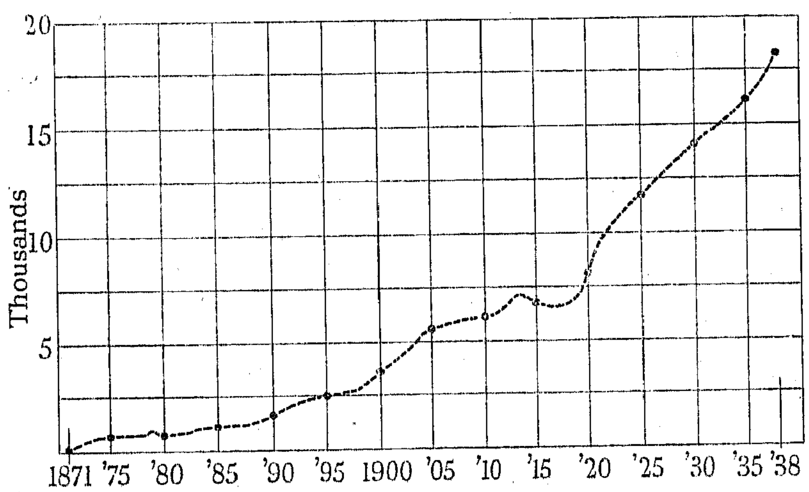

Fig. 7.—Membership of the I.E.E., 1871–1938.

exponential curve. In Fig. 8 I have extended this exponential from 1938 to 1970, when the figure of about 20 to-day would be increased to 562—or 28 times its present value. If the curve were extended to the year 2000, that is to say roughly doubling the period to date since the commercial distribution of electricity commenced, the astounding figure of 10 790 would be attained, or 540 times to-day's figure.

What, then, does the future hold? Are we still only at the beginning of human progress more remote from ultimate possibilities than were the original 100-kW sets from the huge monsters of to-day, or are we nearing a point where the curve will begin to alter and saturation set in, as in the familiar magnetic saturation curve? Or is the world faced with a sudden collapse of civilization when the curve will drop to zero? Who shall say?

On the other hand, if progress is to continue at an increasing rate in electricity and in the amenities of civilization generally, what has the future in store for us in 100, 1 000, or 10 000 years—periods, after all, quite short compared with the life of man on earth?

And what is it all for? Why this terrible rush and hustle? Why are we all concentrating on trying to do things more quickly, to produce things more cheaply, to displace more and more labour?

Are we not rapidly reaching a stage when, were it not for the war, we might with advantage cry a halt and sit down quietly to enjoy the fruits of our labour? Are we not like the man who spends all his time and energy in amassing wealth so that he never has the leisure to enjoy it? Or are we tending towards a better state of civilization, once the present upheaval is at an end, when a few hours' work per day will suffice for all our needs, and in which the rest of our time will be available, and will be used for culture, study, and the improvement of our mental and moral outlook and of our physical well-being?

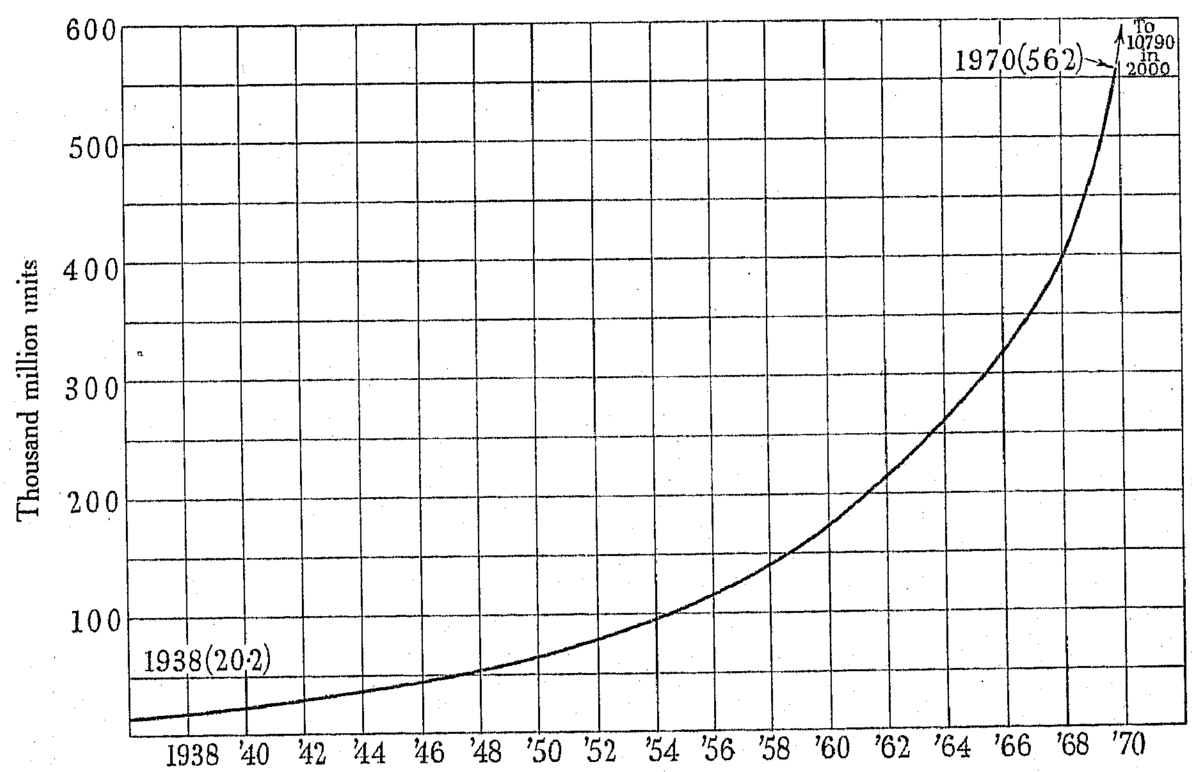

Fig. 8.—Exponential curve indicating the possible development (as indicated by units sold to consumers) in the next 30 years.

NORTHERN IRELAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By J. F. GILLIES, B.E., B.Sc.(Eng.), Ph.D., Associate Member.*

"DEVELOPMENTS IN INSULATING MATERIALS"

(*Address delivered at* BELFAST 17*th October*, 1939.)

INTRODUCTION

The continuous growth in the scope of electrical engineering has made increasing demands on the materials used in the construction of electrical apparatus and plant. This is particularly true in the case of insulators. It is proposed, therefore, to deal with the nature of some of the problems which are encountered in the choice of insulating materials for use under varying conditions and with some of the materials which have been developed to meet the more stringent requirements of modern electrical engineering.

It was sufficient for the early electrical engineer that an insulating material should act as a barrier to the flow of electricity and that it should be durable in service, but the advent of high frequencies has brought with it new problems. Thus bakelite, which finds such wide application at power frequencies, is found to be quite unsatisfactory at high frequencies, and its place can be filled with advantage by a material such as American whitewood which the power-trained engineer would treat with contempt. Such anomalies have led to wide research, with the result that the engineer is now presented with an almost bewildering range of new materials, many of which were previously unknown.

DIELECTRIC CONSTANT

All the anomalies in the behaviour of insulators arise directly from the fact that insulators, or dielectrics, have important electrical characteristics of their own and are not merely materials which do not permit the flow of electricity through them. Electricity was discovered as a frictional effect and attempts were made to store the electricity in water contained in an insulating vessel, such as a glass jar. It was found that powerful sparks could be obtained from the water and that equally good sparks could be obtained in the absence of the water if the glass jar was provided with inner and outer conducting coatings. Thus the Leyden jar was discovered and was termed an electrical condenser because it appeared to condense the electricity and, thus, to increase the electrical effects. It was gradually realized that the glass insulation between the inner and outer coatings played an important part in the observed effects. Benjamin Franklin,[1] who combined the natural philosopher and the statesman, observed that the charge of electricity was carried partly by the glass. Later Henry Cavendish,[2] in his classical work on coated plates, compared the capacitance of a condenser having glass, or other material, as insulator with the capacitance of the same condenser with air between the plates. To this ratio Faraday gave the name "specific inductive capacity," a term which has now been replaced by "dielectric constant" or "permittivity." Faraday showed that the dielectric constant was different for different materials. For most good insulators the value is less than 10, but recent research has shown that there are important exceptions to this rule among the ceramic insulators.

DIELECTRIC ABSORPTION

As in all his work, Faraday's investigations into the behaviour of insulators[3] were thorough and complete. He observed that if a condenser is charged for some time and then discharged, a fresh or residual charge is built up in the condenser. This effect, which had been suspected by Cavendish, is seen in a marked form in impregnated-paper insulation. It appears as if the dielectric absorbs part of the charge and can only return this part comparatively slowly when the condenser is discharged. Hence the term "absorption" is applied to the effect. Thus when a potential difference is applied between the plates of a condenser there are two effects. In the first place a charge appears immediately on the plates, its magnitude being determined by the dimensions of the condenser and by the dielectric constant of the dielectric. Secondly, a further charge is gradually absorbed by the dielectric and an absorption current flows in the external circuit to supply this charge, this current gradually falling to a small value determined by the insulation resistance of the condenser. On discharge, corresponding effects are observed. If the condenser is short-circuited the normal charges on the two plates immediately neutralize each other and then the absorption charge is gradually released, resulting in a discharge current which is exactly similar to the absorption current during the charging process.[4] If, after charging, the condenser is short-circuited momentarily and then open-circuited, the absorption discharge current cannot flow, and, instead, a free charge appears on the plates of the condenser. John Hopkinson, who is better known to electrical engineers as a pioneer in the construction and testing of electrical machinery, studied this effect thoroughly.[5] He found that the magnitude of the residual charge depends on the magnitude and duration of the original charge. Moreover it may change its sign, and, in fact, it varies in a way determined by all the previous charges to which the condenser has been subjected. The conclusion from his experiments was that the absorption effect is due to an internal deformation of the dielectric which persists for some time after the removal of the electrical stress producing it and which dies away slowly. Following this, Hopkinson, acting on a suggestion by Clerk Maxwell, gave his theory a mathematical form based on work done by Boltzmann

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on the theory of the similar after-effects which may arise in a wire subjected to torsional strain. The normal charge of a condenser is, on the other hand, regarded as due to a displacement of electricity within the dielectric which occurs instantaneously without any resistance and which dies away similarly on removal of the electrical stress.

POWER FACTOR

With a direct voltage the absorption current is comparatively unimportant, but with alternating voltage its effect becomes marked as it has not time to die away to an appreciable extent during the short time of one half-cycle. The actual effect is to cause heating of the dielectric, the heating being very much greater than that due to the residual leakage current which flows with direct current. This phenomenon was first observed by Werner Siemens[6] in 1864, when he found that considerable heat was generated in a Leyden jar subjected to an alternating e.m.f. The extent of this undesirable heating is assessed in practice by the power factor of a condenser which has the insulator under consideration as its dielectric. Ideally the power factor of a condenser should be zero, and this is very closely true for condensers with air or a similar gas between the plates. The power factor of liquids and solids varies from such values as 0·00003 for highly purified transformer oil, 0·0003 for mica, to 0·2 or more for the poorer types of insulators.

If the insulator shows little absorption the power factor remains practically the same over a wide range of frequency but increases with rise in temperature owing to the reduced insulation resistance. If absorption is more marked it is found that, as the frequency is raised, the power factor passes through a distinct maximum value, while a similar maximum is obtained if the temperature is varied and the frequency kept constant. Willis Jackson[7] obtained a beautiful set of curves for chlorinated diphenyl, a liquid at ordinary temperatures, which not only show this maximum but also show that at higher frequencies the power-factor maximum is shifted to a higher temperature. Similar curves had previously been obtained by Kitchin and Müller[8] in America for oils with a vegetable base. It is more difficult to obtain such curves for solids, due probably to the more complicated structure and to the greater forces between the molecules of solids than of liquids, but both Jackson[9] and Sommermann[10] have obtained curves for solid solutions of various organic materials in paraffin wax which are very similar to those for liquids and show maxima with change of both frequency and temperature. Although it is not possible to obtain such curves for many solids, it is frequently found that the power factor tends to increase with frequency at some parts of the frequency range, while at very high frequencies there is generally a tendency for a decrease to take place.

THEORIES OF DIELECTRIC ABSORPTION

Many theories have been advanced to explain the occurrence of absorption, some of them being mainly theoretical. Consideration of the source of absorption will therefore be confined to three theories which are essentially descriptive although each is built on a sound theoretical basis.

Clerk Maxwell[11] was the first to suggest that internal currents may flow in a material which is not homogeneous when an electrical stress is applied to it, and that these currents may result in the appearance of free charges within the material. Under the influence of a unidirectional external field they decrease gradually until there is a uniform conduction current throughout the material, but if the field is alternating they form a continual source of loss. This picture applies equally well to a material which consists of a matrix of good insulating properties with particles of semi-conducting material embedded in it.[12] A mechanism of this type may be the source of absorption in insulators which are composed of a mixture of two or more materials, and possibly also in insulators which have a laminated structure.

Absorption may also arise from the presence in the dielectric of free ions which tend to remain scattered throughout the material but which are set in motion by an applied field. If this field is unidirectional the ions are gradually removed from the bulk of the material and tend to accumulate near the electrodes, but if it is alternating they are set into a to-and-fro movement which is resisted by forces of a frictional nature, giving rise to a power loss in the dielectric. Effects of this type occur to some extent in most liquids, and evidence has been found of their presence in solids. In crystalline solids it is probable that free ions occur in the interfacial surfaces of the crystal.

A further important source of absorption has been investigated by Debye,[13] who has shown that in many materials the molecules behave as electrical dipoles. In such molecules, known as polar molecules, the positive and negative charges which compose the molecule have not a common centre of gravity so that their behaviour in an electric field is exactly similar to that of a small magnet when placed in a magnetic field. Thus in the absence of an external electric field they point in random directions, but if a field is applied they tend to align themselves with it. If this applied field is alternating, the molecules tend to oscillate, and this motion is resisted by forces of a viscous nature, with accompanying energy loss. Many common substances are composed of polar molecules and their presence is frequently revealed by an unusually high value of the dielectric constant. As an example of this, water is composed of polar molecules and has a dielectric constant of 80. It is not necessary for the whole molecule to oscillate; for instance, many organic molecules have negatively charged hydroxyl groups attached to various points of a long chain, and energy loss may arise due to the oscillation of this group alone about the axis of the molecule.

It is interesting to note that when treated mathematically these theories all lead to identical results and indicate that, as the frequency is raised, the power factor of a dielectric which exhibits absorption should pass through a maximum value, or possibly through a series of maxima if there are different types of molecules or ions present in the dielectric. At very low frequencies the absorption current has time to die away during a half-cycle, resulting in a low power factor ; at very high frequencies the absorption component of the current tends to become constant while the normal capacitance charging current continues to increase, leading again to a low power factor. Between these extremes a frequency

exists at which the power factor shows a maximum value. At this frequency there is a resonant condition in which the frequency of the applied field is the same as the natural frequency with which the elementary charges in the dielectric, whether they be ions or dipoles, tend to vibrate against the restraining forces acting on them. The effect of raising the temperature is to increase this natural frequency, so that the maximum power factor occurs at a higher frequency. It also follows that at a given frequency a maximum power factor may be observed as the temperature is raised.

PROGRESS IN INSULATION RESEARCH

It is now proposed to review some of the developments which have taken place in the production of insulating materials. In the course of this review it will be seen how recent improvements have been, in a large part, due to a knowledge of the type of molecular structure which is likely to lead to a satisfactory insulator for use under certain conditions. Perhaps the most outstanding development has been in the appearance of a wide range of plastic insulators, many of which have been produced within recent years, while those with good electrical properties are only a section of the much wider range which finds increasing use for many purposes. In addition there are the artificial rubbers, most of them non-inflammable, non-inflammable insulating oils, and the important groups of new ceramic insulators which have outstanding electrical characteristics.

PLASTICS

About 35 years ago chemists turned their attention to the problem of the synthetic production of a resinous material which would take the place of shellac and similar natural resins.[14] It was known already that phenol and formaldehyde interacted to produce a resinous mass, but it was left to Baekeland to perfect the process and to make it possible to carry it out under industrial conditions.

Phenol formaldehyde, well known under the trade name of "Bakelite," belongs to the group of plastics known as "thermo-hardening." It is produced initially in a powdered form which can be pressed into a mould and which hardens to a solid mass when heated to 175° C. In practice, wood-flour is added to the moulding powder to act as a filler, and colouring matter may also be added. The resulting product does not soften again on heating, although it may distort and blister if subjected to an excessive temperature. Phenol formaldehyde has the disadvantage that it cannot be produced in light shades, as these are found to darken and discolour after a time.

For a considerable period phenol formaldehyde was the only available thermo-hardening plastic, but about 15 years ago the urea-formaldehyde plastics were introduced. Urea formaldehyde itself is colourless and consequently it is possible to produce the plastic in a wide range of delicate shades, as, for example, in the well-known "Beetleware" products. There are other formaldehyde plastics, also thermo-hardening, such as aniline formaldehyde and casein formaldehyde, but these are not important for electrical purposes. Glycerol phthalate, known as "Glyptal," is, however, a thermo-hardening plastic of a different type which has found an application in the bonding of mica.

The molecules of plastic materials take the form of long chains which are connected to one another in a somewhat haphazard manner. The effect of increase of temperature is to break some of these points of contact. Since some of the connecting links are stronger than others, the break-up of the structure does not take place at a definite temperature, as in crystals, but is spread over a range of temperature, with the result that plastic materials have no definite melting point. Instead they soften gradually and there is no sudden change from the solid to the liquid state. In the case of the thermo-hardening plastics two forms of structure are possible. In the intermediate stage of manufacture, the units which form the molecule are connected to each other at two points only so that the characteristic structure is a series of long worm-like molecules. On heating, the molecules can slide over each other and so the material softens, but further increase in temperature results in a radical change of structure whereby the bonds between neighbouring units are increased to three or more in number. Consequently the structure becomes rigid and the material hardens.

In the intermediate state the material will dissolve in suitable solvents, and this property has been used in the manufacture of new insulating varnishes. The varnish "Novolak" is obtained in this way from the intermediate state of phenol formaldehyde, and the bakelite paints which are now quite common are produced in a similar way. These varnishes form an excellent substitute for natural resins, such as shellac, for impregnating electrical windings. The windings are impregnated in the usual way and, after drying at a low temperature, are baked at 150° C. In this way the impregnating material is converted to the hard condition. The hardened resin is unaffected by heat and is resistant to the action of oil or water.

Electrically, the characteristics of the thermo-hardening plastics are not outstanding. They have a somewhat low breakdown strength, although it is sufficient for most purposes, and are characterized by poor power factors. This latter defect arises directly from the presence of polar units in the molecules. Thus the phenol formaldehyde molecule has a negatively charged hydroxyl group which is free to oscillate, giving rise to a high power loss in alternating fields. The effect persists over the whole range of frequency, rendering these materials useless for high-frequency insulation. Their use is therefore confined to power frequencies, particularly combined with paper in the form of laminated cylinders and sheet. When used in air, urea formaldehyde has the advantage that breakdown across its surface does not produce "tracking," whereas bakelite tends to "track" and to blister.

Unfortunately the presence of polar units appears at present to be essential in thermo-hardening plastics, but this difficulty does not arise with thermo-plastic materials. Recent progress has made it possible to induce simple units, which are themselves non-polar, to combine and form the long chains which characterize all plastic materials. Polystyrene $(C_6H_5.CH{:}CH_2)_n$, known commercially as "Trolitul" and as "Distrene," which is produced in this way, may exist in the form of long

molecules containing as many as 20 000 carbon atoms, the molecules being intertwined together. Consequently at ordinary temperatures it is a glassy, transparent solid, but it commences to soften at 60° C. Intricate parts can be moulded with ease from the powdered form, and it can be machined if care is taken to prevent the temperature from rising to the softening point.

The electrical properties of polystyrene[15] are excellent and resemble those of ruby mica. The power factor has a value of the order of 0·0003 and does not increase appreciably, even at frequencies as high as 10^8 cycles per sec. The volume resistivity is also remarkably high, being about 10^{17} ohms per cm. cube. On account of its non-polar constitution, the dielectric constant has the low value of 2·7. The extremely low power factor makes polystyrene a valuable material for use at high frequencies, and as the insulator in co-axial cables for communication purposes. It has also been used for jointing and terminating high-voltage cables, although the low dielectric constant is then somewhat of a disadvantage.

The way in which the long molecules of polystyrene are intertwined results in a rigid structure at temperatures below the softening point, and in consequence the material tends to be brittle. It has been found possible, by a process of squirting the liquid under pressure through a fine orifice, to induce the molecules to lie more or less parallel to each other, and the resulting fibre is consequently quite flexible. Threads made from such fibres are likely to have important applications in the construction of cables for use at high frequencies.

Many other thermo-plastic materials have been developed, although not primarily for electrical purposes. Polyindene and polyethylene are non-polar materials with electrical properties similar to those of polystyrene. Cellulose acetate, although similar to celluloid (cellulose nitrate), in constitution and appearance is non-inflammable. It has a dielectric constant ranging from 4·0 to 6·0 and has found some application in the termination of high-voltage cables, where the high dielectric constant serves to reduce the electrical stress. It is water-resistant and can be injected in liquid form into the bushing and allowed to solidify. The molecule of cellulose acetate has a polar moment, which results in a somewhat high power factor and renders the material unsuitable for high-frequency use. Certain polyvinyl derivatives have been found very suitable for coating wires with an insulating covering. The formaldehyde derivative known as "Formex" belongs to this category.[16] It is a viscous liquid which can be applied to the wire by means of a floating die, forming a coating which is more flexible, ages better, and is thinner, than the coating on standard enamelled wire.

NON-INFLAMMABLE TRANSFORMER OILS

It is an interesting fact that the inflammability of many organic materials is greatly reduced if chlorine atoms are substituted for some of the hydrogen atoms in the molecule. For instance, methane (CH_4) is a very inflammable gas, while carbon tetrachloride (CCl_4) is a volatile liquid which is widely used in fire extinguishers.

Reference has already been made to chlorinated diphenyl[17] which, in the form known as "Permitol" or "Pyranol," is liquid at normal temperatures and has characteristics very similar to those of transformer oil. As chlorine atoms are substituted for some of the hydrogen atoms in the molecular structure, the oil is non-inflammable and is valuable for use in transformers installed in positions where the fire risk must be reduced to a minimum. The molecules have a chemically stable structure, being somewhat similar to those of a normal transformer oil with a napthene base, and consequently the oil has the resistance to oxidation which is required in transformer oils. No alterations are required in the design of the transformers except that, on account of the comparatively high cost of the oil, the tank volume should be reduced as far as possible. Chlorinated diphenyl has a permanent polar movement and so high dielectric losses might be expected. Actually, as has been already mentioned, it shows the resonance effect in a marked form so that, although at temperatures below zero the power factor may rise to 0·2 at 50 c./sec., at ordinary working temperatures the power factor falls to values of the order of 0·01. At audio frequencies the maximum power factor occurs at 10° C., but at frequencies of the order of 10^6 c./sec., the maximum power factor has moved to a temperature of 35° C., while at low temperatures the power factor is not unduly high. Thus chlorinated diphenyl is an excellent example of a polar liquid which has good dielectric characteristics provided it is not used under conditions of temperature and frequency which produce a reasonant effect.

ARTIFICIAL RUBBER

One of the outstanding successes of organic chemistry has been the discovery of the butadiene plastics, which have properties very similar to those of natural rubber.[18] The pure butadiene is a thermo-plastic material, but when mixed with sulphur and heated a permanent solid is obtained similar in properties to vulcanized rubber. If two of the hydrogen atoms in butadiene are replaced by chlorine, a compound known as "Neoprene" is obtained with practically identical properties except that it does not burn readily. Consequently it forms a suitable insulator for fire-resistant cables.[19] As its insulation resistance is inferior to that of normal vulcanized rubber, the practice has been developed of applying the insulation in two layers, the inner layer being natural rubber while the outer layer is composed of this fire-resistant artificial rubber. Both layers are then vulcanized together. A sample of house-wiring cable insulated in this way, after being held in a flame for 60 seconds, continues to burn for a period of only 20 seconds or less and damage is confined to a few inches on either side of the part exposed to the flame. Ordinary vulcanized-rubber cable subjected to similar treatment would continue to burn furiously.

Various other artificial rubbers have been developed,[20] such as the polyvinyl chloride "Keroseal" and different derivatives of butadiene. Some of these show a strong resistance to corrosion and are relatively unaffected by oil, ozone, and sunlight, but in general they have not the good dielectric characteristics of natural rubber.

CERAMIC INSULATORS

An important modern development in insulating materials has arisen from the discovery that certain

ceramic insulators have excellent high-frequency characteristics. It has been found that there are two groups of ceramic materials with unusual electrical properties.[21] The steatite group, which includes the materials known as " Frequentite," " Calan," and " Calit," is marked by a very low dielectric loss at high frequencies, the power factor at a frequency of 10^7 c./sec. being of the order of 0·0003. The dielectric constant of these materials is about 6, and although it is not unusually high it is higher than that of most materials which show such a low loss. The ceramics of the steatite group are derived from soapstone and consist of finely divided magnesium silicates. The firing process gives them a dense crystalline structure which results in a high mechanical strength although they are somewhat brittle. The second group consists of materials derived from rutile, a crystalline form of titanium dioxide which is characterized by a dielectric constant of 173 in the direction of the crystal axis. The various materials, such as " Condensa," " Tempa," and " Kerafar," in this group are obtained by firing this material with suitable binders and have dielectric constants varying from 40 to 60. In spite of this high dielectric constant, the power factor of the rutile group is only slightly higher than that of the steatite group. The rutile group is remarkable in having a negative temperature-coefficient, but this can be neutralized by combining members of this group with members of the steatite group which have a positive temperature-coefficient. These materials find an important application in the manufacture of condensers for use at high frequencies, the high dielectric constant resulting in small overall dimensions. The advantages claimed for such condensers, in addition to the small size, include low power factor, negligible temperature-coefficient, and electrical and mechanical stability.

Little is known of the reasons for the peculiar properties of these materials. The low power loss is probably due to the rigid molecular structure. The power loss increases at lower frequencies and in the rutile group where the increase is very marked it has been suggested that this is due to an absorption mechanism of the Maxwell type. The high value of the dielectric constant is attributed to the peculiarities of the atomic structure.

The ceramics tend to absorb a certain amount of moisture when placed in atmospheres of high humidity, and this may lead to an increase in the dielectric power loss. Thus it has been found that under these conditions the power factor of frequentite may rise to 0·001 at a frequency of 10^8 c./sec.[22] At low frequencies the power factor increases further and shows a marked maximum at 100 c./sec., when the power factor may rise to 0·5. Apparently this loss is due to ions, arising from the presence of moisture, which are adsorbed, mainly into the surface structure of the frequentite.

CONCLUSION

Enough has been said to indicate the progress which is being made in the development of new insulating materials. Much of this progress arises from the guidance of fundamental principles in producing the required structure in the material, and is but a further example of the truth that there is no real boundary between pure and applied science. One hesitates to prophesy regarding the future, but the aim of the research worker cannot be better expressed than in words used by Dr. W. D. Coolidge in acknowledging the award this year of the Faraday Medal: " To follow in the footsteps of Faraday is a privilege indeed. To have succeeded in pressing a little farther along the paths he pointed out brings a satisfaction which itself sufficiently rewards the effort."

Acknowledgments

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SHEFFIELD SUB-CENTRE: CHAIRMAN'S ADDRESS

By F. S. NAYLOR, B.Sc., Member.*

(*Address delivered at* SHEFFIELD *18th October*, 1939.)

Within the last few months considerable responsibilities have been imposed on the electrical engineers controlling almost every class of electrical undertaking. As far as the municipal and company undertakings are concerned, these responsibilities have been defined broadly in the Civil Defence Act, part 5, where it is laid down in clauses 27 and 28 that measures must be taken to secure the due functioning of their undertaking in the event of war. It is laid down quite clearly that each undertaking must make a report under penalty, and that the Minister for Civil Defence shall instruct the undertakers to carry out such measures as he considers necessary. Outside the public utility undertakings, under clause 31, the railway companies may be required to make a report stating what measures they have taken for securing the due functioning of their undertaking, and it is clearly specified that this report will cover the execution of work, and the provision of accommodation, plant, materials and equipment, including stocks of stores, with a view to providing and maintaining railway services in the event of hostile attack. It is quite clear that the Civil Defence Act requires public utility undertakings to take very considerable steps and defines in some detail what these steps shall be.

This Act came into being at the beginning of the present year, and the major part of the ground has already been covered by these undertakings in putting its provisions into effect.

It was only during June of the present year that the similar responsibilities to the electrical engineers controlling the industrial electricity undertakings were made manifest in the Ministry of Supply Act. These measures are similarly far-reaching, although they may not be so closely defined as those for the corresponding public utilities. These responsibilities affect very directly a large number of electrical engineers in the country, and it is clear that very unusual measures are required to deal with the situation now existing.

Clause 12 of the Ministry of Supply Act requires that any person carrying on an undertaking to produce articles for any Government Department directly or indirectly must take proper measures to secure the due and continuous functioning of the undertaking in the event of war, and if any person or company fails to do so he shall be liable on summary conviction to be fined not exceeding £100, with other penalties even more severe.

In the explanatory memorandum to this clause it is clearly specified that such undertakings must carry out whatever protective measures may be considered necessary to protect essential plant from air-raid damage. Details are given of the contribution which the Government will make for such protective measures, and it would seem that an industry working wholly on Government contracts would receive a grant to cover the whole cost of this protection.

At the moment the position appears to be that works of a capital nature will be covered by a grant equivalent to the standard rate of income tax (i.e. a grant of $27\frac{1}{2}$ %) on the reasonable capital sum expended. In addition, Government Defence Departments will pay, as part of the cost of their orders, a further part of the remaining $72\frac{1}{2}$ % of the capital expenditure proportionate to the amount of work for the Government which the contractor is carrying out, compared with the total work in hand.

Since times are moving rapidly, the basis of the above may have been altered by the time this Address is delivered, yet in essence the principle remains that suitable contributions are proposed to works carrying out Government defence contracts.

Turning to the practical matters of ensuring the proper functioning of an industrial undertaking, this indeed is the task of many of us as a normal responsibility, and our organizations are adapted specifically to deal with normal emergencies which arise.

Expressed in a few words, they clearly comprise the maintenance of :—

(*a*) A continuous supply of electricity to all parts of the undertaking.

(*b*) A continuous working of the various electrical drives and equipment throughout the works.

In addition to this we must visualize, however, carrying out the same responsibilities under conditions very different from those existing normally. We have had little experience of the conditions under which these responsibilities will be imposed, and I think it is true to state that most of the accepted ways and means have been built up largely from experience abroad, from certain tests taken in this country, from official pamphlets and instructions, and very considerably from a theoretical approach to the subject.

It is generally accepted, for example, that main transformers should be surrounded by high brick cubicles 14–18 in. thick, and that it is preferable to install the radiators themselves as an entirely separate unit, separated from the transformer through a division wall by means of oil piping, the oil supply along which can be quickly isolated by remotely-operated oil valves. Steel canopies $\frac{1}{4}$–$\frac{3}{8}$ in. thick are considered to be adequate protection against incendiary bombs, and similarly canopies over main switchgear have been accepted as the correct thing, with the construction of dwarf walls and oil drainage to remove safely any inflammable materials which may, if allowed to spread, bring about the complete destruction of the whole

* Thomas Firth and John Brown, Ltd.

equipment instead of only such small sections as are damaged.

Some of the latest practices in the installation of transformer and switch-houses recommended by the Electricity Commissioners in respect of stations of major importance, generating or controlling supplies of electricity, have been considered as going largely toward covering risks which may ensue under hostile attack. As early as 1936 the Air Raid Precautions Department of the Home Office issued their memorandum A.R.P. C.2 entitled "Air Raid Precautions for Electricity Undertakings," which was again issued in 1938 and covered a very valuable ground. In this memorandum there has been stressed the necessity for the provision of additional spares owing to the difficulty of securing the rapid manufacture and delivery of equipment in time of war. This memorandum points out that the accumulation of spares for the replacement of essential gear which may be damaged is of the first importance, and that a specially large stock of cable and other repair materials should be kept in depots spread over the undertakings' areas. It is also of value to note that it is strongly recommended that the co-operation of outside repair contractors should be secured for the purpose of any scheme of air-raid precautions. The memoranda issued by The Institution of Civil Engineers this year also helps in visualizing the problem, although probably one of the best publications is that issued by The Institution of Structural Engineers comprising the report of the Committee of A.R.P. published in 1938. This report is based on the practical experience of aerial attacks in Spain and China during 1937 and 1938. As a general rule this published information has helped materially toward schemes of protection within industrial undertakings. It mostly covers recommendations on the standards of protection to be provided with regard to the material thickness of the protecting media. The application of these methods has brought with them attendant problems in satisfactory ventilation, a point which has rather been overlooked in the advice given. All these methods generally cover physical protection, partly by shielding and partly by separation of the plant.

Extensions to these methods, though not quite in the same category, are the provision of ring mains, alternative electricity supplies, fire-fighting installations, and the like. We do not know whether the principles adopted are going to be satisfactory, for it is impossible to know at this stage the magnitude of the risk. We can be sure, however, that whenever damage occurs it is of vital importance to have the means quickly available of replacing the damaged plant or repairing the damage as soon as possible.

Under the Civil Defence Act the Central Electricity Board is empowered to acquire reserve stocks of plant and equipment to the amount of £3 millions, and it can be taken as a *sine qua non* that a not inconsiderable portion of this will go toward the purchase of large spare transformer units, which are easily the most vulnerable items of plant in any electricity transmission and distribution system. The question of large spare transformers is specifically one which must be dealt with in considering the pooled resources of industrial undertakings in this (and for that matter in any) district. A survey showed that amongst the large steelworks in this area, if each undertaking catered for one spare bulk-supply transformer then not less than seven 15 000-kVA transformers would be required at a cost of, say, £50 000, whereas by pooling the requirements three such transformers, or even two, would be quite sufficient for all the needs, so far as they can be estimated at the moment. I think this one example shows that if each of the large steelworks in Sheffield were to purchase and maintain additional spares and take on additional repair staff for the excessively bad conditions which we believe will arise as a result of an air raid, the cost is going to be a very considerable item. Already A.R.P. costs are undergoing considerable criticism; some corporations, boroughs, and urban district councils, have been quoted recently for their disregard of national economy, and while public bodies may possibly be able to continue on these lines it is quite impossible for industrial concerns to adopt similar practices, and the only satisfactory means of reducing in any marked degree the expenditure which must inevitably be incurred on these precautions will be the pooling of repair facilities and of the spare equipment which must be obtained.

While fully agreeing with what has been said in the foregoing, one may now with every justification ask how this pooling of repair capacity and spare plant can be put into practical effect, in this district for example.

This matter has already received very full consideration by the Sheffield and District members of the Iron and Steel Federation, and there is already an A.R.P. Electricity Committee comprising the electrical engineers responsible for their industrial electrical undertakings. Considerable investigations have already been made of the total spare capacity and total repair capacity in this area. With regard to the former, a short-term policy has been agreed whereby for a period of 3 months offers of spare equipment have been made, and these have been tabulated pending the formation of a permanent pool under a long-term policy. With regard to the latter, a questionnaire has been issued designed to indicate approximately the total electrical repair capacity in the district and to show up any weaknesses which exist.

What I have now to say may or may not be acceptable to you as a fit and proper part of my Address, but I put this forward as one scheme which can easily mature from the present activities. You will be aware that the Ministry of Supply is empowered to make grants to ensure the provisions of the Act—in what more fitting way could these powers be applied than by a grant for the purpose of purchasing an agreed pool of spares for the concerns in this district? The appropriate committee exists which can specify even now the requirements for such a pool and which is in a position to appoint a small executive committee and, if necessary, a small staff for dealing with the routine of financial operations which will arise. Each member can purchase from the pool as required, and he in his turn can be reimbursed under the Act in ratio to the amount of Government defence work his company is handling. Such a Committee should be empowered to define the total repair capacity

necessary and employ part of such a grant to install repair plant where such gaps exist. To my mind these are essential A.R.P. activities and only require official status to be given to an existing responsible Committee to put them on a practical working basis.

Let me turn to a further aspect of this subject. I have drawn attention to the legal considerations of the Ministry of Supply Act, and have indicated the responsibilities imposed. With no little misgiving I have even taken the bold step of proposing very briefly a course to be taken to fulfil those duties. I realize, however, that one cannot put forward a suggestion which may necessitate the complete adjusting of one's attitude toward one's responsibilities, particularly at a time when these are unduly heavy. One must of necessity be cautious and, indeed, sceptical that any new and untried departure from normal practice will be of real help.

I should like in a few words before I close this Address to try to indicate where we stand, and to show in spite of our conservatism that this is rather a natural asset than a natural failing ; that in none of us is there anything which could seriously prevent the course I have outlined very briefly from coming into being.

Engineers as members of a profession have been accused from time to time of having an outlook of self-sufficiency which is centred upon the purely engineering aspect of their work. They have been accused of being satisfied that technical competency is the limit of their activities. It has been said that professional expertness has been the object without any regard to the broader social understanding and willingness to co-operate elsewhere for controlling more fully the effects of their work. Outside observers have even quoted the pronounced objects of the various engineering Institutions to prove how self-centred are these points of view. It is only recently that there has been any real refutation, by public action on our part, that this narrow-mindedness did not indeed exist, for it was not until 1937 that an Engineering Public Relations Committee was considered by the major Institutions and was set up provisionally to enlighten the public on the whole course of an engineer's work and to impress his point of view upon other people. In America there is what is known as an American Engineering Council which endeavours to act as the national medium through which the engineering profession as a whole can serve national welfare. Our own and other major Institutions were not slow this year in setting up a voluntary National Register many months before the compulsory Register was drawn up ; their object was to serve the country by the course which has a universal application, namely that of pooling all our professional resources so that the best and most applicable can be quickly and without delay picked out and used to the best national advantage.

At the risk once again of raising a controversial issue, I should like to draw your attention again to the specific manner in which (under the Civil Defence and Ministry of Supply Acts) the line of action has been laid down which must be taken by the Central Electricity Board, the municipal and company electricity undertakings, and the railways, all of which are large group undertakings with no uncertain voices when Bills such as these are being formulated. There is no similar body except perhaps our own Institution which can point to the necessity for strong action under national emergency, to cover vital loop-holes in the maintenance and spare resources which are all-important in ensuring that continuity of output with which duty we are charged. I stress without hesitation that this aspect of the national emergency is in serious risk of not receiving proper consideration, owing not to any lack of interest on the part of those in authority, but rather to the fact that there has been no specific body to draw attention to its vital necessity.

It is a striking thing that in the list of reserved occupations for the purpose of the National Register, in no place is the maintenance electrical engineer, in contradistinction to the fully-trained Chartered Electrical Engineer, given any significant position at all ; he is placed under the heading "Fitters," sandwiched between a maintenance electrician and an armature builder. It is not because the engineer solely on maintenance work is not recognized, but because engineers and contractors solely concerned with maintenance do their jobs too well and indeed, therefore, their lights are for ever hidden beneath innumerable bushels, or it would be more in keeping with the times if I said that therefore they approach too nearly 100 % obscuration. I am suggesting that possibly there may be some slight truth in the general belief that they are too quietly satisfied with what they do, and that this frame of mind is a dangerous state of affairs under present conditions.

It is not enough to say that each should prepare on his own ground to deal with trouble ; the problems will be far too great, the action to be taken in an emergency would be something of which we have had no precedence.

In the same way as it has been considered necessary to double and even treble the police and fire services under the Civil Defence Act, so it is equally vital to expand the repair services associated with the large industrial undertakings to maintain that all-important continuity of output without which any country must surely fail.

I have endeavoured in this short Address to state very briefly the legal position in which electrical engineers stand with regard to their responsibilities to secure the due and continuous functioning of the undertakings they control in time of war ; and I have touched on some of the practical aspects of carrying these out, with a few references to the guidance which has been available during the last 12 months. I have indicated generally the procedure which is being adopted by undertakings other than those in the industrial field, and have tried to point out the desirability of economy in the methods to be adopted in increasing the repair capacity and spare equipment. I have then put a suggestion to you for carrying out these responsibilities. Finally I have made an appeal against an attitude of *laissez faire*.

I cannot close this Address without repeating once again that we have a responsibility to face and that it is our duty to face it and deal with it with a broad outlook and on a scale of dimensions which must cover not only our own individual affairs but those of everyone. We in this district have made a start on these lines, and it is my sincere belief that as, and when, the trouble arises we shall be repaid a hundredfold for the work we are doing.

TEES-SIDE SUB-CENTRE: CHAIRMAN'S ADDRESS

By M. CLINE, Associate Member.*

"FAULTS ON POWER CABLES AND OVERHEAD LINES: THEIR CAUSES AND SOME METHODS OF LOCALIZATION"

(*Address delivered at* MIDDLESBROUGH 1*st November*, 1939.)

It is intended to give a brief review of the causes of faults and of the technique referring to their localization. This subject has always been to the fore in connection with the distribution of electricity and is of vital importance at the present time.

CAUSES OF FAILURE

Cables as a means of transmission of electricity undoubtedly have an advantage over overhead lines as regards reliability, apart from their freedom from the various atmospheric disturbances that affect the open wire.

This advantage lies in the manufacture when the product is prepared under factory conditions, which can be regulated.

The joints, however, which are manufactured on site, have been and (in spite of improved methods of jointing) still are the most prolific source of trouble. This does not appear as an inherent cause of failure immediately following its completion—rather does a time element come into play.

Various factors, some of which affect the cable as well, tend to create a weakness which did not previously exist. Examples are:—

- Migration of compound.
- Interaction between different compounds.
- Heat cycles, due to load, creating voids.
- Sheath weakness near plumbs being aggravated by road vibration.
- Discharges from points and other places of high stress, mostly due to poor jointing.
- Movement of cores, produced by excessive loading or ground subsidence.

Referring to the cable, the quality and mechanical strength of the paper insulation is important, firstly to avoid conductive impurities and to prevent cracking of the paper during the handling of the cable, and secondly to permit the manufacture of a firm core and thereby minimize voids. Ionization taking place in these voids brings about a change of state in the resin compound, with a resultant lowering of dielectric value.

Accuracy in the laying of the paper insulation is important; for example, a source of weakness would be initiated by the edges of successive layers coinciding through part of the dielectric.

The cable, having been tested at various stages of its manufacture, is now laid and jointed and duly re-tested at the appropriate voltage. This was generally carried out with alternating current and the method still has its supporters, but mainly owing to the bulk of apparatus necessary, as compared with the more compact direct-current pressure-testing set, this latter at the present time is practically universally used, especially for field work. The d.c. set has another advantage, in its inclusion in the high-voltage bridge for the more obstinate type of faults.

Having been put on load, the feeder may complete years of service without a single failure. On the other hand, through one cause or another, occasional troubles may be experienced. One of the first of these that can occur is mechanical damage. The paths and roads are chock-a-block with mains and pipes of all kinds, and the occasional lack of co-ordination between the various authorities, coupled with the fact that in modern road-breaking a certain amount of brute force is employed, tends to maintain this risk of damage. The mechanical excavator is very powerful and can sever even an armoured cable and bring the two ends to the surface with the remainder of its load. This type of fault certainly has one decided advantage in that the focus of the mischief reveals itself in most instances. In others nothing may be observed, as when a fencing-pin is driven through the ground into a cable whose electrical protection is lightly set.

The origin of other failures varies. Certain cables may develop a fault through some inaccuracy in the laying of the papers making up the insulation. If the machine carrying out this work has mal-operated, various kinds of hidden blemishes are brought about which affect the useful life of the cable. Ionization taking place at these points is a factor which will cause it to break down sooner or later.

Migration of compound becomes a serious matter when the cable is laid considerably off the horizontal plane, and in severe cases renders that portion of the insulation both dry and brittle and very liable to crack.

The most frequent cause of faults is water obtaining access to the insulation through the lead sheathing and wipes, which may be split, porous, contain pinholes, crystallize and fracture through vibration, sustain either electrolytic or chemical action, or be pulled apart by ground subsidence.

With overhead lines, the erection is carried out wholly on site and is of the nature of a mechanical engineering job to an electrical design. This design sometimes does not fit in with local conditions, and repeated failures

* North-Eastern Electric Supply Company, Ltd.

of the same type are the result until the matter is rectified. These instances illustrate this point:—

The use of a standard-type insulator in a district which has a dirty or salty atmosphere.

The absence of a continuous earth wire on lines traversing country where thunderstorms are prevalent.

The general failures on overhead lines may be ascribed to:—

- Lightning.
- Birds.
- Dirty insulators, particularly when associated with fog.
- Cracked insulators.
- Bad weather conditions, especially wintry gales with ice-loaded conductors.
- Pole dividing-boxes and sealing-ends.

Regarding this last item, these boxes have the same possibilities of failure as joints, plus some peculiar to themselves, in so far as they are more exposed to the elements and their watertightness is dependent on packings of various kinds which deteriorate with time. Their position, also, at a height above the general level of the cable, aids in compound loss through migration.

LOCALIZATION OF FAULTS

Overhead Lines

When a failure occurs on an overhead line, assuming it is ascertained that the cable terminating ends are not at fault, by testing them when disconnected, an attempt is usually made to find the cause by visual means, by having the line patrolled. This can be carried out remarkably quickly by employing the proper organization and making plans in advance for every line so that each man is allocated to a certain section.

Transport is also so arranged that no delay occurs, either in the distribution of the men or in the collection of their reports, which can then be transmitted to headquarters from the nearest telephone.

However, where long lines are concerned, this method is still not sufficiently rapid for present-day purposes, and an attempt is made to limit the patrolling to sections known to contain the fault, by the use of fault indicators situated at various points along the route. In the case of a through line fault indicator (cable slip-over type) this would consist of a relay operated by means of the resultant unbalance of current caused by the fault. Assuming the fault to be fed from one direction only, the indicators beyond the fault, from the point of supply, would not operate, and as these indicators are conveniently placed at road cable-crossings and terminal points an examination of these at the outset will save considerable time.

The earth-fault indicator, however, uses the fault current flowing down the earth wire to actuate the relay. If these are fitted to each pole, an indication is given at the actual pole where the fault exists. When, however, lightning has been the cause, several relays may operate on either side of the affected pole, owing, no doubt, to surges.

A point to be noticed is that false readings can be obtained through the circulating currents from a neighbouring low-voltage network earth fault, affecting the high-voltage fault relay at the substation. To avoid this the high- and low-voltage earthing systems must be kept separate.

Another type of indicator utilizes a transformer inserted in series with the line and is therefore much more costly than the others, but is also more reliable.

The employment of automatic switches and fuse isolators helps to localize the trouble by giving visual indications. In the latter case this effect is brought about by the fuse wire itself maintaining the fuse-holder in its normal, nearly vertical, position against a spring action. When the wire fuses, a pivoted latch, which was held in position by the wire, is moved by the spring action and permits the whole fuse-holder to pivot around its lower support into a position away from the live side. This will then indicate the section containing the fault, which can then readily be found by the methods already outlined. Where indicators are not fitted at each pole, and patrolling of the line fails to reveal the trouble, as in the case of a punctured, but not shattered, insulator, each pole of this limited section is climbed.

Pole dividing-box faults frequently show themselves by signs of flashed insulators, compound leaks, or, quite often, by mechanical damage to the box casting. If no signs are visible, the fault is treated as a cable fault.

Cables

With cables a different technique has to be adopted, on account of their usual inaccessibility. Following the occurrence of the fault, the first objective is to obtain a picture of what has happened at the point of fault by means of tests taken with an insulation-testing set and resistance bridge. With these aids much time can be saved, as the necessary data are obtained to indicate the nature of the next test necessary, i.e. to localize the fault.

There are many combinations possible with three cores, each core having the possibility of being continuous or discontinuous and the insulation being good, bad, or indifferent, and therefore a serious effort should be made at this juncture to obtain a true idea of the state of the fault.

The most common case will involve one core faulty to earth, with one or more good cores available. The Murray loop test will probably be the most suitable to use here. This is produced by coupling the faulty and good core at the distant end and forming a Wheatstone bridge by means of a slide wire or variable resistors, which become two arms of the bridge, the other two being made up of the lengths of core along each path from the fault to the testing end.

Certain precautions should be taken or erroneous results will be obtained. No resistance should be introduced at the distant end, the connection between the two cores being made as perfect as possible. Under normal practical conditions, where switchgear forms the terminating ends of the cable, the testing contacts should be examined on each occasion that they are used for this purpose.

If the cores are not uniform in section throughout their length, equivalent lengths must be worked out for those parts which depart from the normal section.

Tests must be taken from both ends, not only to check against a complete error due to neglect of the above precautions, or even faulty instruments, but to determine more accurately the precise position of the fault. There may be disagreement in the positions obtained from these tests, and in the ordinary way, for small differences, the fault will be found between these two points, the cable being excavated for over this distance.

When, however, this variation amounts to a considerable length, which cannot be dealt with in this way, a solution to the problem may be evolved from an examination of the causes. A common cause for this difference is a false figure having been taken for the loop return core. However, if there are two good cores available the possibility of this error can be eliminated by coupling both of these with the faulty core at the distant end and then carrying out two tests, firstly the normal loop test with the battery to earth and secondly a test with the battery, suitably reduced in value, connected to the second good core. This latter test, when using a slide wire, will give the relationship between the faulty core and its good return, as in fact an artificial fault has been placed at the distant end. The position of the fault is then indicated by the direct ratio between the two tests in terms of the route length of the faulty core only.

Poor insulation of the cores used for the return will also produce divergent results. If this low insulation can be assumed to be equally distributed, the effect of this alone will be to indicate in general a fault at the distant end and, coupled with the actual fault, would give a resultant position somewhere between the fault and the far end. So it follows that the best result will be that obtained at the end farthest from the fault.

These points bring up the question of the degree of accuracy obtainable, a matter of prime importance when it involves cost and time in breaking up main roads. This accuracy is bound up with several factors, some of which have already been mentioned. Others having more or less effect on the usefulness of the test are indicated here.

The insensitivity of the galvanometer, as we are dealing with microamperes, will put a definite limit to the accuracy.

The resistance of the fault has a double action in reducing the accuracy of the test, (1) by reducing the available current and e.m.f. to operate the galvanometer, and (2) by approaching the figure of natural insulation resistance of the core and thereby increasing the error caused by the combination of these resistances.

The possibility of the existence of more than one fault must not be discounted when the accuracy of the test is at stake. It is rare that a high-voltage cable is so affected, but it happens sometimes in auxiliary cables, owing to the fact that an incipient fault can be allowed to develop, for easier localizing, without affecting the use of the cable. While this process is on its way—a matter of months, perhaps—there is an opportunity for another fault to occur. For this reason a trial test should always be taken and noted, even though the fault resistance is very high. If this is not done, excavations may be carried out, on apparently sound tests, at a point far from either fault.

High-Voltage Bridge

It occurs quite frequently that, on account of the very high resistance of the fault, a considerable voltage is required for the test. Furthermore, in joints where fluid compound has been employed, and sometimes in cables, the fault may seal up and prevent any test being taken with the ordinary bridge. The high-voltage bridge is used in this case. The principle is the same as before but a specially insulated slide wire and galvanometer are used, operated with a rod of insulating material, and supplied, from a transformer and rectifier, with the necessary high voltage to break the fault down and keep it in this condition while the test is being taken.

Fall-of-Potential Test

This test, which has the advantage of simplicity, can be undertaken when conditions are unfavourable for a loop test, for example a breakdown between cores but not to earth and with no good core available. In this case a steady current is passed down one faulty core via the lead sheath or earth, and voltage readings are then taken at each end between the two faulty cores.

The voltage-drop from each end to the point of fault is thereby obtained, the readings being directly proportional to the distance.

When dealing with earth faults, if good cores are available various other means of obtaining the voltage-drop are possible. The good and faulty cores are coupled at the distant end, and an accumulator is included in this circuit at the testing end. Voltage readings taken from each core to earth will give the voltage-drop to the fault in each case, and these will be directly proportional to the distance. A source of trouble that may occur here is that the fault itself may be developing an e.m.f., which may compare in value with the potential difference that is being measured and thus introduce an error. Also, earth currents are likely to affect the readings as the fault is part of the voltmeter circuit.

To assist towards the accuracy of the test, the battery should be reversed and another series of readings taken—the average of these being used. In doing this, care must be taken regarding the polarity of the readings. A reversal of the circulating current should produce a reversal of polarity of the voltage-drop. If it does not, it follows that the voltage of the fault is greater than the voltage-drop along the section of conductor being tested, and to obtain the true average of fall of potential along the conductor half the difference of the two readings should be taken, instead of half the sum as in the normal case.

Voltage-Drop Test along Sheath

Occasionally a fault does not reveal its precise position even though the cable is exposed, following a test, at the assumed position. In this case a current is passed along the faulty core with the sheath or armour as the return. If, with a galvanometer, the voltage-drop is measured across 2–3 yards of sheath at a time, the fault will be indicated by a change of direction of the current upon reaching its position.

This method is useful on cables in power stations and the like where the cable is readily accessible in racks, tunnels, etc. Under certain circumstances, however,

it may not prove satisfactory in these places, owing to the many heavily loaded cables producing circulating currents which affect the galvanometer.

Capacitance and Inductance Tests

When the core has been burnt through or perhaps parted, by a joint pulling, a bridge loop test is no longer admissible and, according to the conditions, the following methods may be employed.

(a) Fault resistance high, say 1 megohm per mile of cable.

Method—D.C. Capacitance.—In this the faulty core is charged by applying a suitable voltage and discharged through a galvanometer, the deflection of the needle being noted. This procedure is repeated with a good core, if available, and the distance to the fault will be directly proportional to the respective deflections obtained.

If a good core is not available, tests are taken from both ends of the faulty core, the deflections again being in proportion to the distance of the fault from each end.

During the test all other cores and parts of core should be earthed or a serious error will be introduced as the true relative capacitance will not then be measured.

If the test can only be taken from one end on account of the prevailing conditions, rendering all other cores unsuitable for this test, a comparison must be made with a standard condenser of known capacitance. Then, with a knowledge of the capacitance per mile of cable, derived from the manufacturer's test figures, the distance to the fault can be calculated.

This latter test does not lend itself to great accuracy, as the factory figures taken on the drummed cable tend to differ slightly from the capacitance when the cable is laid.

Equivalent lengths must be worked out as before, but this time the capacitance per unit length is the ruling factor. Hence it is important to keep accurate records of the supply of cable from different manufacturers, as this factor varies considerably.

(b) Fault resistance of medium value, say 10 000 ohms per mile.

Method—A.C. Capacitance Bridge.—The d.c. discharge method would give very inaccurate results here and an a.c. capacitance bridge would be best employed. In this a Wheatstone bridge form is used with equal-resistance ratio arms. The third arm consists of a variable condenser and resistor in parallel, the fourth arm being the condenser formed by the faulty core and earth. An alternating current, generally at about 800 c./sec., is applied and a telephone receiver acts as a means of obtaining the null point. This point is obtained when the capacitance and resistance of the variable condenser and resistance respectively equal the capacitance of the core and the resistance of the fault, respectively. The capacitance is then as before, compared with that of a good core.

Difficulties experienced are:—

(1) Trouble in determining a silent null point, owing to the presence of harmonics in the oscillator.

(2) Poor accuracy on account of the difference between the apparent and true capacitance, which varies with the length and leakance. Arbitrary correction factors based on experiment can be employed, but, taken within the limit specified, the test can be very useful on a difficult type of fault.

(c) Fault resistance low, say 10 ohms.

Methods:

Inductance Test.—All capacitance tests are rendered useless by the presence of this low resistance to earth, and therefore a comparison of the inductance may be taken, using an a.c. bridge as before but with the resistance-shunted condenser in the opposite arm of the bridge.

Similar difficulty is experienced regarding the necessity for a considerable correction factor for a fault resistance much above the value quoted, but again the test can be useful on what may be a difficult type of fault.

Search-coil Test.—A method that is likely to give good results in the above case is the search coil, consisting of a number of turns of wire on a wooden frame, the ends of the coil being connected to a telephone receiver.

A source of alternating or intermittent current at low frequency is applied between the faulty core and earth, and the induced current picked up, when the coil is taken over the route of the cable, produces a marked note in the telephone. On passing the fault there is a noticeable diminution in the volume of sound.

Misleading results can be obtained when the fault resistance is high and a long cable is under test, by the transference of capacitance current to the far side of the fault, thus causing no discernible difference in sound on passing the fault.

CONCLUSION

Referring to present-day war conditions, it is assumed that a great increase of speed in repair of faults will be necessary. This will affect not only those caused by enemy action, the positions of which will be self-revealing, but also those which occur normally.

A cable fault cannot be localized quickly by hasty, approximate methods, and therefore the most important factor in reducing the time taken is the accuracy of the tests.

Regarding the emergency repair of cable faults under these conditions, there are quick methods which utilize cold compounds, former-spaced cores, mechanical joints and no plumbing. By these means an extremely rapid repair is possible, taking only a fraction of the time necessary for a proper permanent repair, which would have to be carried out at some more opportune time.

DUNDEE SUB-CENTRE: CHAIRMAN'S ADDRESS

By A. A. B. MARTIN, B.Sc., Associate Member.*

"ELECTRICITY IN RELATION TO NATIONAL AFFAIRS"

(*Address received* 13*th November*, 1939.)

For this Address I believe it will be appropriate to take heed of the intense national activity which has characterized recent months, and consider how the progress of the electricity supply industry is affected by major events in the life of the nation, and how far these matters are the concern of electrical engineers.

There is one preliminary point I should like to make. In a scientific paper the writer is concerned with experiments, facts, theories, and conclusions, all in their proper sequence. An essayist, on the other hand, has no such restrictions and no definite conclusions to be reached; he merely follows wherever his subject leads. Under the title "Electricity in relation to National Affairs" I propose to avail myself of the freedom of the essayist.

The electricity supply industry, like a human being, has two roles—that of existing in an individualistic way, and that of existing as part of a community. When danger threatens, a human being assumes his role as a member of the community and subordinates his individual outlook. So it is with electricity. The two roles of electricity may be visualized by considering the industry in two ways; first, as the service which benefits individuals by penetrating into their homes and factories—the individualist role—and secondly, as a great single organization which will always, even in times of national emergency, adequately fulfil its part in the national machine—the collective or national role.

Although we may have complete confidence in the future, this present time is, relatively at least, a time of danger. The collective or national role of electricity is, therefore, of greater importance to-day than it has ever been before, and accordingly it is the collective or national role of electricity with which this paper will deal.

Present-day national affairs are apt to be dominated entirely by international affairs which, at first sight, have no connection with electricity. The latter is essentially a domestic matter. Unlike many industries, it is entirely devoid of any kind of international repercussions. Its prosperity is not achieved at the expense of foreign competitors and therefore it cannot cause economic distress overseas. In addition, there are reasons why electricity should try to keep itself equally free from the problems and controversies which are internal to this country. In its own private affairs it is singularly fortunate. For instance, electricity is not dependent on a re-armament campaign to keep it going. Perhaps electricity's greatest good fortune is its unlimited future. The ultimate extent of its use, its ultimate technical achievements, and its ultimate influence on human affairs, are all still beyond conjecture. With such scope inside their own province, electrical engineers might reasonably seek to concentrate on their work alone, and ignore all the disharmonies of the outside world.

This would, however, constitute a very superficial view. In examining the question more thoroughly, various questions arise.

First, one might ask whether any responsible person, as a citizen, is entitled to ignore international, national, social, economic, industrial and similar problems. However profitably and more pleasantly an electrical engineer may be able to fill his life, is he, from an ethical point of view, entitled to seek such immunity? While the bearing of this question should not be overlooked, the answering of it is clearly outside the scope of a Chairman's Address. A more pertinent question, and one to which an answer may be attempted, is: "In the light of the world to-day, in war time or in peace time, will the interests of the electricity supply industry be better served by engineers who concentrate on purely electrical matters, or by engineers who give a proportion of their time to the study of national affairs?" The expression "national affairs" is used as a conveniently vague title which may be taken to embrace civics, history, economics, psychology, and all other studies which facilitate understanding of national problems.

Although war is the dominating influence at this time, I believe that, quite apart from this incidence of war, the tempo of life to-day is such that the need for wider knowledge generally is urgent, and this need is particularly noticeable in the electricity industry.

That the best interests of electricity service, studied by themselves, and the best interests of electricity service, studied in conjunction with national affairs, are quite different, is easily demonstrable in time of actual war such as this, or even in time of uneasy peace when war in the future is a possibility.

In wartime, with unknown dangers threatening, the electricity supply industry, like all national civil organizations, must make comprehensive preparations to avoid damage or minimize the results of damage. Towards this end, everyone, no matter how small or remote his particular responsibility appears to be, must study the offensives and defences of modern warfare.

In an uneasy peace many problems will rely for their solution more on the political uncertainty than on purely technical considerations. A problem of this nature is the question of power station maximum sizes—whether to develop further the super-power station practice, or to revert to a policy of comparative decentralization.

Even apart from wars and rumours of wars, even in the event of a peace so real that we could rule out future crises altogether from our computations, there are other new important factors in national life to-day which we must take into account. On the one hand, there are

* Central Electricity Board.

increasing doubts about the why and the wherefore of it all; painful modernization is being forced upon time-honoured beliefs, and men's philosophies are being assailed. On the other hand, there is the tremendous intensification of all efforts, ruthless speed and ruthless efficiency. It is an age of interdependence; no organization fits adequately into the machinery of life to-day unless it studies the ways, needs, and aims of its fellows. Lack of mutual understanding represents the rust which must be rigorously excluded from that machinery.

Then these are far from being normal times; they are highly critical. If there is need for wider outlooks and wider understanding in normality, that need is immeasurably greater to-day. Electrical planning, involving, as it does, large capital outlays, must always be long-term planning. Anticipation of the future to-day is complicated not only by the speed and intensity of peace-time efforts but also by this war which has descended on us, the length and severity of which cannot be predicted. Even ordinarily, there is always the difficult task of nursing, within the industry, not only the simple relationships of supply undertakings with each other, with national electrical organizations, with the machinery of finance, local government and national government, but also the abstract relationship which exists between the industry as a whole and the nation as a whole. These are matters requiring far more than mere technical knowledge.

When it is recalled that electricity has already been responsible for the enormous development around London—for it was the establishment of a good electricity service in the areas adjacent to London which attracted the numerous small factories, which in their turn brought the new populations—it affords an instance of electricity influencing the life of the nation in more ways than is generally supposed. That it is an important contributor in the campaign for better living conditions is well known, but its possible use as a planner and controller of population trends is less appreciated. Envisaging a future where local interests and national interests are both proportionately safeguarded, where electrical engineers are less officials and more directors of a united and more definitely-policied industry, there may be many similar important problems and possibilities. Interdependence, intensification and statistics, alike, are all increasing. Surely it would be unwise for engineers to confine themselves to the narrow limits of electrical engineering even during their early years. These wider matters involve all that is known of the science of community living; indeed they involve more—they involve the fundamental beliefs and philosophies underlying that science. The effective progress of our industry in co-operation with the progress of our national life requires that, in the future, our engineers will not try to master these matters only when the need to know them is forced on them, but will count them worthy of study from their student training days onwards, and so handle them with the maximum effectiveness when the time comes.

Consideration of electricity and its relationship to national affairs in a more practical manner can be made by reference to the history of the industry during and since the last war. This in turn may facilitate consideration of present-day problems, of the position of electricity in this new war, and of its strength or weakness at this critical time. While the experiences afforded by the 1914–1918 war are of interest, we must remember that no war is ever like the one that precedes it. The present war will inevitably produce its own problems and difficulties.

In the course of the last war, electricity overcame many difficulties and realized many creditable achievements, but it will be far more instructive to examine the other side of the picture. The stress of those days exposed more than one weakness in the structure of the supply industry. The hugely increased industrial effort found itself at times handicapped by inadequate local power-generating resources. In 1917 the coal shortage led to a scrutiny of all coal consumers, electricity works included. Exposed then was the wastage involved by the system of independent local generation. Since then this wastage has been stopped and the combined generating resources of the whole country have been pooled through the national grid. In this war no longer will the shifting of location of demands, that is to say the establishment of factories in new areas and their cessation in old areas, seriously embarrass the electricity supply industry. The fullest possible utilization of all power resources, including new water-power resources, will be possible now where it was not possible before.

Also exposed was the error of the industry in not having a national supervising and co-ordinating body such as the Electricity Commissioners. As early as 1916 the Board of Trade appealed to electricity owners to help the industrial effort by connecting their power systems with those of their neighbours in order to establish small regional grids. This appeal met with no response. The difficulties of such linking-up were considered too great. They were the differences of systems, frequencies and voltages, financial difficulties and lack of co-operation between owners. This last seems a particularly regrettable reason at a time when the nation was in great difficulties, but it must be remembered that willingness by individuals is useless if first these individuals do not create machinery through which to apply their willingness. The machinery required was some responsible co-ordinating and guiding body, which the industry did not then possess.

This lack was remedied in 1919 when the Electricity Commissioners were created. The establishment of the Central Electricity Board in 1926 was also the result of war-time experience. The idea of pooling generating resources was actually much older than the war, but the war demonstrated the urgent need of applying it. The seven-year delay between 1919 and 1926 was occasioned by the prior trying-out of a scheme of regional pooling on a voluntary basis. Thus the experience of the last war was the direct cause of the two major developments which have so far occurred in the administrative history of the industry—the setting up of the Electricity Commissioners and the establishment of the Central Electricity Board.

It will perhaps be a permissible digression at this point to draw attention to the tremendous importance of the Central Electricity Board as an air-raid precaution. Remembering that it is the collective value of the electricity supply industry which counts at a time like this, the latter is obviously considerably strengthened by the fact that all major centres now have grid transformers in addition to their own generators on which to rely. The value of this addition is immeasurably greater

than its simple additive value. The idea of large cities being suddenly deprived of electricity for many months is abhorrent in peacetime. In wartime the seriousness of such a deprivation could scarcely be over-emphasized, especially if one thinks of cities such as Coventry and Birmingham, where so many essential engineering industries are concentrated. Yet, if there were no national grid, such a deprivation would be not improbable since power stations could be destroyed by a single bomb. The grid substation is, of course, equally vulnerable. The important point is that, however great the damage, there cannot be any chance of a large town being rendered sterile for a year or more due to loss of electric power. The grid supply alternative is fundamentally different from the power station in that it is capable of quick recommissioning. Switches and transformers can be quickly replaced, overhead lines can be repaired and necessary improvisations can all be effected within a few days. If previously all generators were already fully loaded, of course the outputs of the destroyed generators cannot be replaced—on the other hand the flexibility of the grid will always enable the total available generator capacity to be used where it is most required.

There are thus two tremendous advantages. The grid substation does not imply only the difference between a duplicate supply and a single supply. It is the difference between loss of all supply for a few days instead of for a year or more. Secondly, if many power stations suffer in air raids, the generators of all those which escape can be diverted to the most urgent needs. The enormous value of this aspect of the grid system need not be regarded entirely as a happy coincidence. If not specifically foreseen in 1926, it was realized then that the co-ordinating and planning of generation was bound to reveal new and unsuspected values in its working out, just as a policy of uncontrolled *laissez faire* would lead to new and unforeseen complications.

Apart from these aspects, I do not propose to refer to air-raid precautions in considering the situation to-day. The air menace appears rather like a cloud which has hovered overhead all this past year, and on which our eyes have been continually focused. The cloud still has not burst; but whether it is a laden cloud or only empty vapour it should not be allowed to obscure the whole horizon. If this war should enlarge itself and be prolonged, other dangers will appear. Because the dangers of air raids have already been so much emphasized, while the dangers inherent in a long war seem seldom to be considered, I propose to stress only the latter.

If any dangers threaten, it is necessary to prepare against them. To prepare adequately one must conjure up the worst form the dangers may take, and it is therefore essential to assume an attitude of the extremest pessimism; no other attitude is logically permissible. If the war should enlarge itself, and should run a course unfavourable to us, we must anticipate a huge increase in the demands for power, and this increase will be located quite differently from what would normally be expected. As an instance, that quarter of the nation's requirements which are at present centred round London may have to be largely dispersed elsewhere. Both the increase and the changes of location would further over-burden construction departments, already over-burdened in making good air-raid damage. It can be appreciated that these things alone would tax to the uttermost the combined resources of the industry. But there may be further difficulties. Personnel might be short-handed in all grades. In such dangerous times toll of personnel will be taken, if not by military requirements, by air raids and increased illness due to the strain and conditions of life. The obtaining of materials and fuel, and the maintaining of communications, will all be rendered more difficult.

It might seem that these troubles would be enough, but other evils may be at work as the war drags on. Persistent attacks on the morale of the reduced staff that attempts to carry on will have their effect. In addition to the other dangers and difficulties, provision must be made to counter the evil effects of propaganda, hunger, disillusionment, war weariness and similar things.

There is of course a limit to what is humanly possible. These dangers are all outside our control. They will beset all organizations and industries equally. How far others will be able to resist and overcome them we do not know, but we must consider how we are prepared. How are we prepared? How indeed can anyone prepare against so many contingencies? This question may not be properly answerable but this much at least can be said: an industry or an organization will best survive such an ordeal if it ensures beforehand that its administrative structure is strong and resilient. In the case of electricity one might visualize a limited number of supply undertakings, all with identity of purpose and internal structure (which would require them all to be of comparable size), able to co-operate freely amongst themselves, and all co-ordinated and supervised by an adequately empowered national guiding body. The criterions would be efficiency, co-operation and simplicity, the last being essential to ensure the necessary flexibility of the industry to adapt itself to any contingency.

A glance at the present structure of the electricity supply industry of Great Britain reveals over 600 different undertakings. Comparableness of size is non-existent, the ratio of the large to the small being of the order of 1 000 : 1. Identity of purpose too is non-existent. The policy of any individual authority is largely under the control of local or private interests. These interests vary, and from time to time many contrasting statements of policy are made. Internal structures, too, are varied; among companies a few are large and independent, others are too small to make proper progress, while some are tied to larger companies which may represent financial or manufacturing interests, or interests other than those of good electricity service. Symbolic of this confusion is the fact that legislation called for in 1936 was laid aside because it was controversial, and even now, 3 years later, lies as it was dropped.

Such a structure cannot possibly be considered completely efficient, simple and flexible.

The structure of the electricity supply industry that we have at present is the result of normal evolutionary methods. Normal evolution in this country is apt to consist of avoiding any change until circumstances render the change absolutely necessary. Laws require much time to prepare and are difficult to enact; accordingly, they are always devised to last for as many years as possible. There is a stability about such an arrange-

ment; it precludes the possibility of any rash moves, and it is well suited to long-established institutions. It is comparable with a system devised to meet the needs of a settled elderly person who slightly changes his mode of life not oftener than once in 10 years unless some crisis occurs. In its childhood the electricity supply industry had to manage on this system, despite the irreconcilability between the requirements of a young child and an elderly person. Legislators did their best, but no one could predict accurately the way the industry would grow up. Electrical legislation frequently required modifications and additions. Inevitably, the structure became complex and unwieldy.

Whether the adolescent is now as healthy as he ought to be may not be really known until it is seen how far he is able to resist attacks of illness. The war of 1914–1918 was a major illness. Electricity survived, but two major operations were necessitated—the establishing of the Electricity Commissioners and the Central Electricity Board. The next epidemic was the industrial depression of 1931. Electricity escaped entirely, but this was due not to its powers of resistance being great but to its fortunate individual nature which renders it immune from certain germs. Thus it escapes such things as foreign competition and swelling unemployment figures. But we may consider what this epidemic might have revealed about electricity by consideration of its effects on a non-immune industry such as steel. Steel suffered so badly that a most drastic overhauling was found necessary. Of steel at this time, history relates that " The steel industry was warned to put its own house in order before it could expect support from the State. Steel at this period (1932) still lacked an authoritative single voice to speak for the industry or guarantee a collective policy on the part of its members." We cannot avoid reflecting how even now, many years later, electricity cannot feel itself entitled to escape these two criticisms. Where is the authoritative single voice, or what is the collective policy of its members? It may not seek support from the State, but two years ago it sought legislation. Did it have its own house in order before approaching the State? Parliament was expected to pronounce on the political suitability of the proposed measures, but controversy was simultaneously raging about the technical and administrative merits inside the industry. Should not the industry be agreed within itself first before seeking legislation?

It appears that the administrative and structural progress of the electricity supply industry is a spasmodic movement, dependent for its initiative on major national crises such as wars. The initiative comes from without both in its original conception—the national crisis—and in its practical application—a government-established committee to investigate and report. This is surely too haphazard an arrangement for present-day needs. Both initiative and machinery should be the responsibility of the industry and not of outside factors.

Another matter deserving of thought is the way in which possible reforms of the industry have to be severely restricted. One may contemplate such measures as reducing the number of separate undertakings or even voltage standardization, but one must not suggest the complete re-drawing of the areas of supply authorities. Although it is known that the present areas make no pretence of being planned as economic areas, and that many of the present boundaries are, from a distribution point of view, absurd—for instance those which follow city boundaries—such a reform, on account of the complex structure of the industry, must be dismissed as being outside the realm of practical politics. The increased overall distribution efficiency possible by planned areas may be known, but it must be considered futile to attempt to secure it.

Before this is accepted, careful study should be made of the barriers which enclose " the realm of practical politics." These barriers are not always impregnable. Dictators sweep them aside. Was not even temporary German-Russo *rapprochement* considered impracticable a few months ago? With war as the excuse, our own Government lays its barriers aside, as in its evacuation scheme it has laid low the erstwhile strongly held belief that " an Englishman's house is his castle."

We do not like either dictators or war, but their example, together with the inexorable demands for more speed, more efficiency, and more outputs, universally made in these years should urge us to attempt, without delay, the reduction of those barriers which impede real administrative electrical progress. Ordinary evolutionary progress will wear them away, but at a very slow pace. Are there no means by which electrical engineers can facilitate and accelerate the disintegration of these barriers?

In an attempt to find means for this task, help will not come from concentration on technical problems, nor indeed from concentration on any form of purely electrical problem. These barriers are the work and property of all sections of the community, and their elimination, however controlled or gradual, is a delicate matter. Help will come from other studies—such things as civics, sociology, political economy, history, psychology, or, to use the vague but comprehensive expression in the title of this Address, national affairs. Suppose these matters were seriously embodied in all electrical engineers' training—the fundamental principles and ground work in studenthood, and the building up of knowledge continued from then till such time as they are required—can it be doubted that the cumulative effect of such combined efforts would achieve results past all comparing with normal " evolutionary " results?

In all industries, in all spheres of life, it is being discovered now how important is the need for much wider outlooks and wider knowledge. The benefits still waiting to be reaped will depend on how much these further fields of knowledge have already been harvested. In industries where little technical interest attaches to their workings, the pursuit of other interests leads to early inroads on these fields. On the other hand, one of the principal features of electricity is its tremendous technical interest. This is so great as to be able to monopolize with ease the attention of electrical engineers of all ages. Because of it, we may assume that in electricity's domain the further fields do not beckon as elsewhere. Electricity thus has a handicap in this important matter of the wider outlook, and, for this reason, we may further assume that the need to correlate progress with national affairs is exceptionally great in our own industry.

EAST MIDLAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By S. J. R. ALLWOOD, Associate Member.*

(*Address received* 23*rd October*, 1939.)

I propose to review the conditions which govern the consumption of electrical energy for industrial purposes, and to illustrate by means of a few examples the changes in the condition of this load due to modern developments.

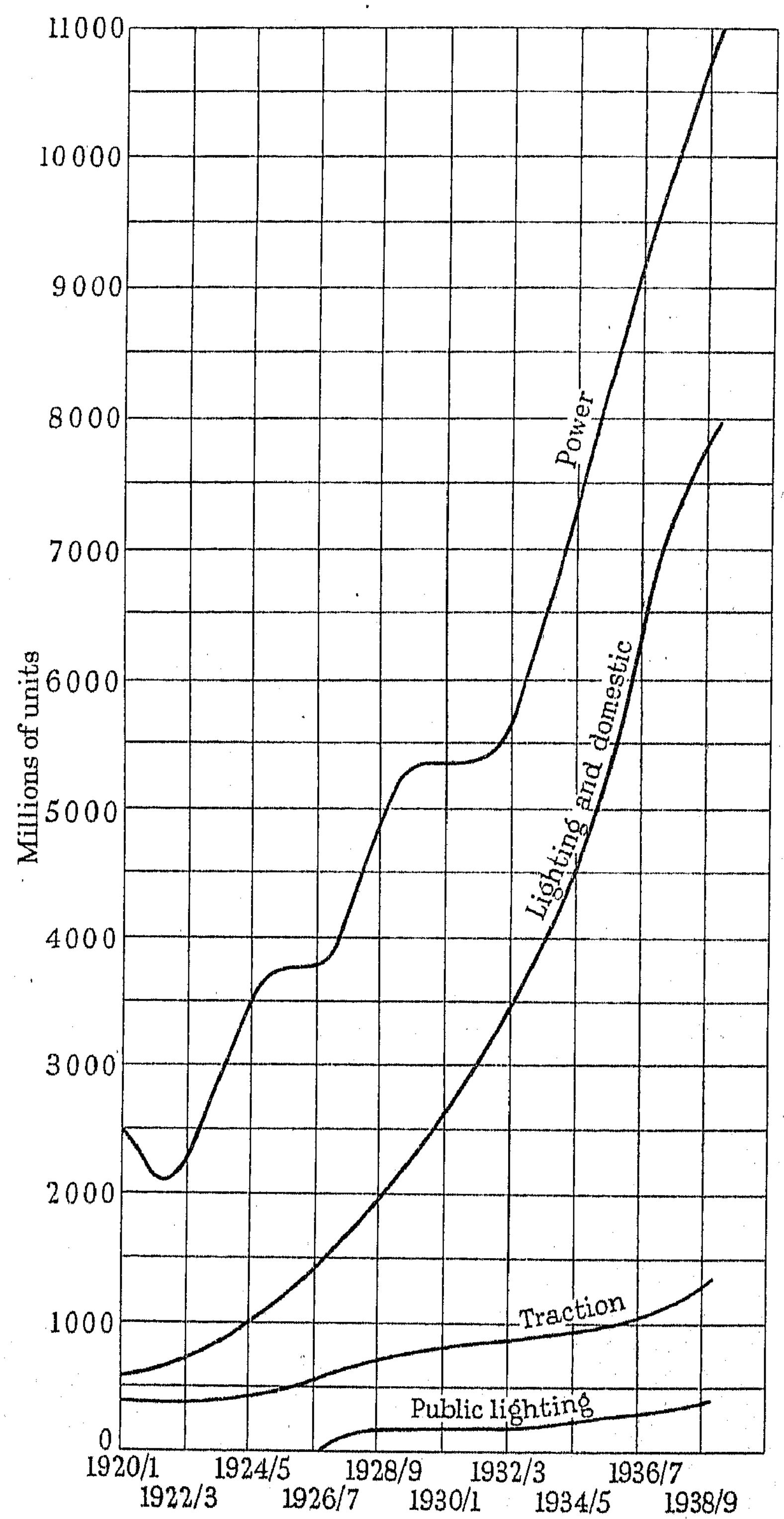
It will be appreciated that, since the preparation of the greater part of this Address, war has unfortunately broken out and will, of course, in the immediate future, affect the factors governing the conditions referred to, but I think it quite reasonable to assume that after a period of post-war instability these conditions will again appertain.

In 1938 the units distributed by authorized undertakings amounted to 23 089 millions ; of these 10 700 millions were consumed by industrial power consumers, and 7 800 millions by domestic consumers, the remainder being taken by traction, public lighting, etc. It will be seen from this that the consumption is 46·3 % industrial, and 33·7 % domestic, and although the sale of electrical energy for domestic consumers is developing rapidly, the sale for industrial power (which is also developing rapidly) is still by far the greatest.

The graphs given in the Figure show the total annual consumption for the above-mentioned groups of consumers, and we see from these that since the depression period of 1930–31 the industrial consumption of energy has maintained a steady increase, whilst the domestic consumption from that period until the end of 1936 shows an ever-increasing demand. The rate of increase from then up to the present shows a falling-off, and it is reasonable to assume that, although an appreciable increase in demand for this purpose will be maintained, the rate of increase will be lower than hitherto.

It is desirable that the tariffs applicable to each class of load should bear a definite relation to its load factor, and that the development of any particular class of load should not take place at the expense of another. The industrial consumer, whose load factor is usually higher than any other, should be encouraged in his development by the application of equitable tariffs, and progressive consideration should be given to the restrictions applied to his service. This will tend to develop this load, particularly in the case of the smaller consumer, where it frequently occurs that the conditions under which he wishes to use electrical energy are such as to react unfavourably against his development, due to the conditions under which load is taken to meet modern methods of production.

With the development of the national grid and the comprehensive distributing systems of supply undertakings, the area of supply has now been so extended as to make it possible to establish industries in almost any part of the country, and this will, in my opinion, in the future have a far-reaching effect on the distribution of industry over the country. If this is encouraged by favourable conditions of supply its effect will be very



Annual consumption of electrical energy in Great Britain, 1920–1939.

extensive. At the present time, principally owing to the development of transport facilities, there is an enormous concentration, in the London and Home Counties

* London, Midland, and Scottish Railway Company.

Area, of manufacturing firms supplying commodities for home consumption, many of which could be manufactured at the sources of supply. I have in mind at the present time food products.

Referring to the heavier industries, these of course naturally tend to develop in clearly defined areas, and this is very strikingly illustrated when we compare the percentage of units consumed by industrial power with that for domestic supplies on various undertakings; for example :—

Sheffield:
Industrial power = 67 %; domestic = 24·3 %

Birmingham:
Industrial power = 71·5 %; domestic = 19·2 %

Wolverhampton:
Industrial power = 65·7 %; domestic = 20·2 %

whilst examples of industrial cities with mixed industries are:—

Leicester:
Industrial power = 36·5 %; domestic = 56·2 %

Nottingham:
Industrial power = 39·3 %; domestic = 51·6 %

Derby:
Industrial power = 39·1 %; domestic = 50·8 %

It would appear, therefore, that there is prospect of an appreciable increase in industrial consumptions in these areas, given favourable conditions for development.

We have in recent years seen the development of the modern factory wherein large quantities of similar articles, machines, or vehicles (such as motor-cars, railway rolling stock, etc.), are produced by sequence or flow methods, and to exploit these methods fully the maximum flexibility of plant is essential. This means that the machine tools used in the manufacture of products in this way should preferably be self-contained units with their own power units which can be switched on and off as required, in contrast to the older-type machines which were driven by means of line shaft and belting with a common source of power. The machine, being self-contained, can be situated in the most suitable position for the job it has to perform, both in relation to the sequence of the work relative to other machines that may be carrying out other operations on the same article, and also in relation to the supply of raw material and the removal of finished work. In a production shop where sequence working is adopted, the disposition of the machines can be readily altered to meet changes in the production programme, the absence of belting providing free head-room and facilitating the handling of work into the machine by cranes or runways. The general lighting of the shop is also considerably improved. The control of the machine is much easier, the push-button control or short-lever control switch being almost universally adopted. By this the operator is able to control his machine more quickly and without distracting his attention from the work, thus appreciably reducing the non-productive running time of the machine and thereby increasing the output.

It is interesting to note the change in the load conditions due to these methods as compared with group driving by means of line shafting and one motor, and observations made in a large engineering works illustrate this point.

Owing to the nature of the load on a machine tool, the rating of machine-tool motors is usually on the 1-hour basis; but with a group drive, because of the diversity between the various machine tools, the variation of the load on the motor is considerably less and the motor should be continuously rated at the average power demand. The continuous rated horse-power of the motor with a group drive is on the average 40 % of the sum of the 1-hour-rated horse-powers that would be necessary to drive the individual machine tools. This, of course, varies according to the number and type of machines. For instance, a line of shafting driving a group of 20 capstan lathes employed on bolt and screw making required 30 % of the horse-power necessary for the individual machines, whereas a line driving a group of 6 automatic screw machines and 4 capstan lathes required 65 %, the automatic machines having a very high load factor.

From an appreciable number of tests made on both group and individual drives, it is ascertained that with normally-loaded group drives the average load factor on the motor is approximately 60 % and the average power factor 0·75, and that the percentage of energy consumed for no-load running losses, which includes the shafting and belting, is approximately 30 %. With individual drives, however, the average load factor is approximately 40 %, the average power factor 0·6, and the no-load running losses 15–20 %. We see from this that with the adoption of individual drives, because of the intermittent nature of the load, and the fact that a machine tool is frequently not working to its full capacity and thereby not loading its driving motor up to its rating, the power factor of the load as a whole will be lowered, but the overall efficiency of transmission is appreciably higher.

The characteristics and power requirements of a modern machine tool are considerably greater than those of a machine tool of a decade or so ago, the reason being the greatly superior cutting steels now available; consequently much greater rates of removal of metal are now obtainable and considerably higher cutting speeds are possible.

For instance, when using tungsten-carbide tools for machining high-tensile steels, cutting speeds of 700 ft. per min. for finishing cuts are quite usual, and roughing at 60 ft. per min. using high-speed steel is common. The power requirements of a machine tool are directly proportional to the rate of removal of the metal, assuming of course that the tool is in proper condition and that the cutting angle, etc., for the material being machined are correct. For example, the approximate power requirements per cubic inch per min. for a lathe when turning the following materials are :—

Brass	0·286 h.p.
Cast iron	0·5 h.p.
Mild steel	0·59 h.p.
32–38-ton tensile steel	0·714 h.p.
50-ton tensile steel	1·5 h.p.

From this it will be seen that the power requirements of a machine tool for its maximum output are readily assessed on the duties it is designed to perform, i.e. the class of metal it is designed to remove and the rate at which removal is to take place.

It is seen from this that with the greater outputs possible per machine the maximum power requirements of a machine are increased, and for a given output of work the number of machines is proportionately reduced. This results in a higher concentration of load, invariably at a lower power factor.

The use of 3-phase high-frequency current for the driving of portable tools and woodworking machinery (where high spindle speeds are required) is being increasingly adopted. For portable tools using a frequency of 200 cycles per sec. a light, simple, 2-pole induction motor with a spindle speed of 10 000–12 000 r.p.m. is used, giving a considerably greater h.p./weight ratio for the tool than is obtained by machines operating on normal frequency; it also eliminates the use of commutator motors.

For woodworking machinery where spindle speeds up to 24 000 r.p.m. are required, direct-mounted 2-pole motors, with solid rotors mounted direct on the work spindle, are used, operating on 400 cycles per sec. This, of course, eliminates all gearing such as is necessary with 50-cycle motors. The use of these frequencies necessitates the use of frequency changers, and in the case of the woodworking machines these are often mounted in the bedplate of the machine, making a self-contained unit.

These frequency changers are excited from the a.c. supply, and the frequency obtained is given by the expression

$$\text{High-frequency output} = \text{Pairs of poles in generator} \times \left(\frac{\text{r.p.m. of motor}}{60} + \text{frequency of supply}\right)$$

From the intermittent nature of the demand on these machines and the method of excitation, it is obvious that they will operate at a low power factor, i.e. from 0·4 to 0·7, according to the load.

The use of electric welding is increasingly superseding other methods of construction. Fabrication by arc welding is displacing riveted structures and large shell castings, also the manufacture of articles previously made by smithing. Butt or resistance welding machines are displacing hammer forging, whilst spot welding has developed rapidly for sheet-metal work, particularly in the construction of vehicle bodies. Butt and spot welding machines are essentially a single-phase load and their use naturally causes unbalance when supplied from a 3-phase supply, and where 3-phase/1-phase transformers are used the unbalance is 2 to 1; also the load taken is at low power factor. The reason for this low power factor is that the principal factor in the impedance of the circuit is the magnetic reactance of the secondary loop. The load factor on this type of plant is also low, and in a factory where large numbers of machines are in use it is only approximately 10 % of the connected capacity. With arc welding plant the load factor is again low, and in a factory with an appreciable number of machines it is not more than 10–20 % of the connected capacity.

The adoption of alternating current for welding has been successfully developed, and is now quite successful for most applications. The reason for this development is that the equipment is cheaper and more simple than the d.c. welder requiring a motor-generator; it also lends itself readily to the installation of permanent welding circuits in a workshop where welding is the principal operation. It has, however, a very low power factor, approximately 0·4. The explanation is that owing to the instability of an arc on alternating current a series induction regulator having a 92 % reactance is inserted in the circuit so as to mask the fluctuations occurring over the arc itself.

It will have been appreciated from the few examples quoted that the installation of modern equipment tends to reduce the power factor, and at the same time to increase the concentration of load in the production shops of a factory, and in a large works leads to concentrations of demand in defined areas. The load centres of gravity in these areas are the best positions for sub-stations, and their installation at these points is desirable so as to reduce to a minimum the length of low-voltage feeders. It also simplifies low-voltage switchgear, and transformer sizes are kept reasonably small, resulting in the lower rupturing capacity necessary for the low-voltage protective equipment.

It has been seen that the installation of modern equipment tends to reduce the power factor, and as the effective capacity of an installation is inversely proportional to the power factor of the load the cost of the installation will increase accordingly. It is consequently an economy to install correcting equipment in installations of any considerable size.

I have endeavoured to put before you some of the problems involved in modern industrial developments. It is true that the examples quoted have been connected with the engineering industry, but I believe that the conditions in most other industries are similar, and I hope that I have been able to present a true picture of the subject as a whole.

A SLIDING-RATE METER*

By M. UNZ, Dr.Eng., Associate Member.†

(*Paper first received* 16*th February, and in revised form* 15*th May,* 1939.)

SUMMARY

A new type of meter is suggested to replace the existing maximum-demand indicators. The device works in the same way as a watt-hour meter, but integrates the relative values of the units as a function of the demand, instead of registering only the quantities of units consumed. Hence the meter reading does not indicate kilowatt-hours, but a figure which is proportional to the payment due.

The law defining the varying values of the units consumed at different demands is introduced into the meter by modifying its load/speed curve. The new performance of the meter is obtained by altering the features of the magnetic brake.

The constructional details of the proposed braking element are shown, its equivalent electric circuit is considered, and its performance discussed. The reconstruction of the meter characteristic is outlined, and the errors and compensation methods briefly discussed.

(1) INTRODUCTION

Of all the methods for allocating the standing charges according to the consumers' demands, those based on maximum-demand indicators are the soundest from the technical point of view. However, it has been repeatedly stressed that the charges arrived at in this way are, in practice, both unfair and inconvenient to the consumer.‡

Improvements to the demand charging system have been effected by means of peak-load meters, load-levelling relays, and time switches,§ as well as by various refinements of the tariffs, but these have been limited in their application. As a result, either the conventional maximum-demand indicators have had to be retained together with their shortcomings, or else the idea of checking the consumers' load curve has had to be abandoned, even in cases where the diversity of the supply is inadequate.

The tariff problem therefore reduces to the question of a suitable measuring instrument. A meter is required which would automatically fix the price level of each consumed unit as a function of the power at which it is supplied, and integrate such prices to a total amount. The sliding-rate tariff which would thus become possible would be free from all the drawbacks of maximum-demand indicators. The consumer would know that the price of a unit consumed at half load is much lower than that for a unit consumed at double full load. He could endeavour to reduce his electricity bill by improving the load factor to the utmost, but would never be afraid of being penalized for exceeding his usual demands.

The supply undertaking, on the other hand, would have the full benefit of a rational and simple charging system, without the necessity of providing duplicate measuring instruments or wiring. The running charge could be determined according to a block tariff; and substantial reductions could be offered for continuous loads under minimum-payment guarantees.

(2) THE DEMAND-CONTROLLED METER

An integrating watt-hour meter having a curve for the speed characteristic instead of a straight line, as shown in Fig. 1, would serve the purpose. The meter readings would then not be in kilowatt-hours but in what could be termed "key units." These readings would be proportional to the amounts of money due, as in load-rate prepayment meters or in double-tariff meters with a single counter train.

The tangent to the curves at the origin of co-ordinates can be regarded as the characteristic of a standard meter, having the same speeds for small loads as the meters represented by the curves. This tangent will be used as a baseline for the discussion of the meter characteristic; and the ratio of the actual meter speed to the speed corresponding to the baseline will indicate the average increase of the unit price at rising demand, and will be called the "speed increase" or "rate increase" factor. For example, the values of this ratio for Curve C are as follows:—

Load, in kW	1	2	3	4
Speed-increase factor ..	1·04	1·20	1·51	2·50

The curves of Fig. 1 are all shown with a common baseline, but, of course, adequate variation of their shape must be possible to make the meter comply with the price laws required. Various types of curves can then be laid down for standardization. In principle, the shape of the characteristic does not affect the accuracy of the device; it only complicates its calibration; the possible sources of errors will have to be investigated on the same lines as in every other measuring instrument.

The speeding-up effect described above can be obtained in a meter either by making the driving torque proportional to a higher than the first power of the load, or by reducing the retarding torque of the brake. The latter method is constructionally easier, and in addition it has the advantage that the existing driving elements with all their compensating devices can be left untouched.

(3) MODIFIED FORM OF THE MAGNETIC BRAKE

The desired performance of the magnetic brake is obtained by suitably altering the impedance of the induced circuit.

* The Papers Committee invite written communications, for consideration with a view to publication, on papers published in the *Journal* without being read at a meeting. Communications (except those from abroad) should reach the Secretary of The Institution not later than one month after publication of the paper to which they relate.

† Iraq Petroleum Co., Ltd.

‡ *Journal I.E.E.*, 1936, **78**, pp. 685, 693, 696; 1936, **79**, pp. 506, 514; 1937, **80**, p. 578; and 1937, **81**, pp. 451, 459.

§ *Journal I.E.E.*, 1914, **52**, p. 42; 1929, **67**, p. 296; 1936, **79**, p. 514; 1937, **80**, p. 582; and 1938, **83**, p. 823.

The straight-line characteristic is due, as is well known, to the presence in the eddy-current disc of ohmic resistance only. By providing stray reactance in this part of the brake a choking effect is produced, which reduces the current at higher speeds, thus diminishing the torque in relation to the straight-line law. In view of the low rotor speeds, however, it is difficult to provide such additional stray inductance without excessively increasing the weight of the moving system. The constructional arrangement of the brake must therefore be altered. The safest way out then seems to be to move the induced circuit from the rotor into a stationary pole-piece of the permanent magnet, the moving system being used for the creation of a rotating magnetic field, as in homopolar generators.*

Fig. 2 shows an example of a braking element of this type. The brake consists of the permanent magnet A with its pole-pieces B_1 and B_2 and a rotating disc C mounted on the meter spindle D. The top pole-piece B_1 of the magnet is rounded and has an opening in the centre through which passes the shaft D; the radial adjusting screws E provided in it serve to balance the magnetic field. The lower pole-piece B_2 has a spherically shaped

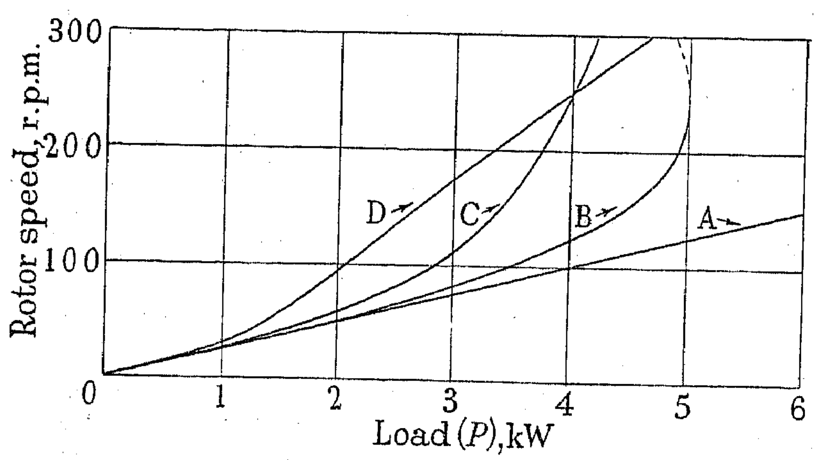


Fig. 1.—Load/speed curves.

annular pole-face and is provided with radial slots for taking the short-circuit cage F of the brake. The form of the slots depends on the amount of stray inductance required. The cage itself is only partly shown in the Figure.

The rotor disc C, of soft sheet iron, is spherical and is provided with four sector-shaped vanes. The disc moves between the two pole-pieces in such a way that the stationary flux of the magnet entering at its solid centre part is transformed into a rotating field, which follows the movement of the vanes. The magnetic lines entering the pole-piece B_2 pass through its teeth and join at the bottom pole of the magnet. If the cross-section of the bottom ring of this pole-piece is made sufficiently large, the resulting total flux will remain practically constant.

Owing to the size of the pole-faces and to the permeability of the disc, the air-gaps can now be made wider than in a standard meter. By making the active surfaces at the top smaller than at the bottom, a greater magnetic flux-density on the upper part of the iron disc is obtained. This results in an upward force which is suitable for magnetic suspension of the moving system.

When adapting the brake to a meter, it is simplest to make the iron rotor independent of the driving disc and to mount it at the bottom of a common spindle. Although the total weight of the moving system is thus increased, the effective weight is smaller owing to the magnetic floating effect. The inertia of the rotor, however, becomes larger; therefore the diameter of the braking disc should be made as small as possible.

The new device is doubtless more sensitive to manufacturing faults and rough handling than an ordinary

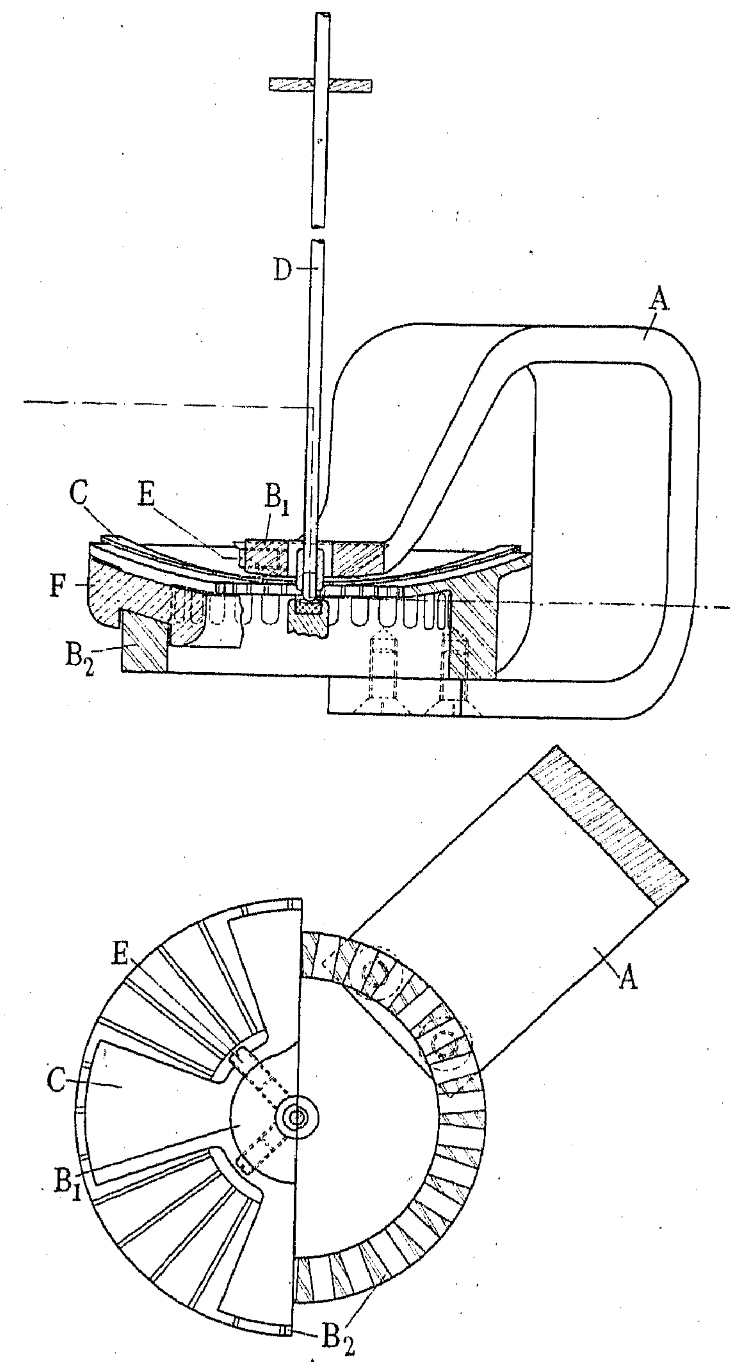


Fig. 2.—Suggested form of magnetic brake.

watt-hour meter. It also shows some additional measuring errors. There is, however, every reason to expect that it will prove much more exact and reliable in operation than the mechanically complicated maximum-demand indicators or peak-load meters.

(4) THE EQUIVALENT CIRCUIT FOR THE BRAKE

The device described above works like an a.c. machine. The pulsating flux density created in it can be resolved into two components, one of constant intensity B_0, and the other an alternating component with a maximum value B (Fig. 3). The inductive effects are to be attributed solely to the alternating component.

* Patent pending.

If we consider first the fundamental sine wave of the field, we find the braking element reduced to a synchronous generator with salient poles and short-circuited armature windings. Since the field system of the brake comprises a permanent magnet of relatively high reluctance, however, the reaction of the induced currents

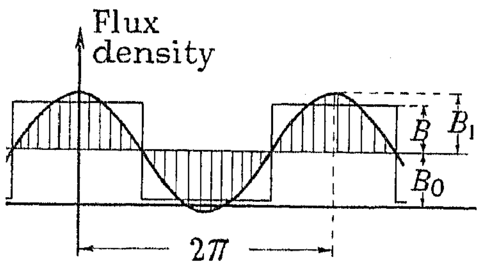


Fig. 3.—Peripheral distribution of the magnetic field.

is very small in relation to the exciting ampere-turns, and can therefore be neglected. Furthermore, if we assume that the iron of the magnetic circuit is not saturated, we arrive at the following solution.

The rotating field induces in the cage e.m.f.'s of frequency

$$f = \frac{pn}{60} \text{ cycles per sec.} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

p denoting the number of rotor vanes and n the number of revolutions per minute. The intensity of these e.m.f.'s is proportional to the effective flux (Φ) of a pole and to the speed of the rotor (n). Thus

$$E = K_1 \Phi n \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If we assume that the secondary impedance of the cage per pole and phase at a frequency f is

$$\bar{Z}_1 = R_1 + jX'_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and reduce the stray reactance X'_1 by means of (1) to its value X_1 at 50 cycles per sec., i.e.

$$X'_1 = uX_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

with

$$u = \frac{f}{50} = \frac{pn}{3\,000} \cdot \quad . \quad . \quad . \quad . \quad . \quad (5)$$

it follows, for the current in the cage,

$$\bar{I} = \frac{E}{\bar{Z}_1} = \frac{K_1 \Phi n}{R_1 + juX_1} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

After dividing by u, the numerator of the last fraction becomes independent of n. On introducing the constant

$$E_c = \frac{3\,000}{p} K_1 \Phi \ [V] \quad . \quad . \quad . \quad . \quad . \quad (7)$$

the current in the cage becomes

$$\bar{I} = \frac{E_c}{\frac{R_1}{u} + jX_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This expression applies to the equivalent circuit shown in Fig. 4. This circuit represents the case of an imaginary induction motor without any primary impedance, working with the slip u. The physical assumptions made above for the synchronous machine apply also to the induction motor, and the value of u checks with equation (5).

The standard circle diagram in its simplest form can be used for the circuit shown in the Figure, and the

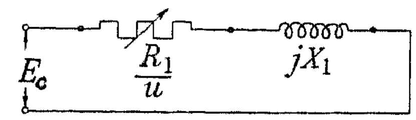


Fig. 4.—Equivalent diagram for elementary braking circuit.

torque of the braking element can be obtained from it by the well-known graphical method. We prefer, however, to continue the investigation with regard to the performance of the meter as a whole.

(5) THE CHARACTERISTIC OF THE METER

Mathematical Analysis

Under stationary conditions the retarding torque is counterbalanced by the driving torque of the meter. If we neglect the friction losses, the mechanical work done by the brake is equal to the electrical energy of the induced currents. Let T_b denote the braking torque, ω the angular velocity of the rotor, and z the number of phases in the braking cage; then

$$T_b \omega = EI \cos \psi \, . \, p \, . \, z \quad . \quad . \quad . \quad . \quad . \quad (9)$$

By substituting in (9) the values of E and I obtained from (2), (5), and (6), also the angular velocity $\omega = 2\pi n/60$ and power factor $\cos \psi = R_1/Z_1$, we arrive at an expression for the braking torque, namely

$$T_b = K_2 \, . \, \Phi^2 n \, . \, \frac{R_1}{R_1^2 + \left(\frac{p}{3\,000} nX_1\right)^2} \quad . \quad (10)$$

in which the constant K_2 is given by

$$K_2 = \frac{30}{\pi} pzK_1^2 \, [-]. \quad . \quad . \quad . \quad (11)$$

Unlike the retarding torque, the torque due to the driving element is the same as in a standard meter. If P is the measured power, V and I the measured voltage and current, R_d the equivalent resistance of the driving disc, and F, G, and H the constant factors, the resulting torque exerted on the driving disc is given by

$$T_d = F\frac{P}{R_d} - G\frac{V^2}{R_d}n - H\frac{I^2}{R_d}n \quad . \quad . \quad . \quad (12)$$

The first term of this expression denotes the driving torque proper, the second the retarding torque due to the shunt field, and the last term the retarding torque of the series field.* The forces resulting from asymmetry of the magnetic distribution and from friction, and the influence of the stray inductance in the driving disc, can be neglected over the observed range of performance.

The retarding torque of the shunt field is, for constant voltage V, proportional to the rotor speed. Therefore it can be considered separately as a straight-line torque, which should be superimposed on the reactive braking system according to the method shown below.

The braking component due to the series field, as given by the third term of (12), is proportional to the speed n

* *Journal I.E.E.*, 1936, **77**, p. 356; and 1937, **80**, p. 15.

and to the square of the measured current I. In standard meters this component produces small deviations from the straight-line law, which are the source of the well-known error at overloads. Since the suggested arrangement works in a range of currents and speeds similar to that of a standard meter, the retarding effect of the series field can be neglected in the general investigation.

For a uniform movement (i.e. zero acceleration), we can write

$$T_b = T_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and substituting in this equation (10) and the first term of (12), we arrive, after some transformation, at

$$P = \frac{K_2}{F}\Phi^2 n \frac{R_d}{R_1} \cdot \frac{1}{1 + \left(\frac{p}{3\,000} n \frac{X_1}{R_1}\right)^2} \quad . \quad . \quad (14)$$

This is an expression for the load/speed curve of the meter with a single reactive brake circuit. In view of the fact that the values of R_d, R_1, X_1, and Φ above can be considered constant, we introduce the parameters

$$a = \frac{K_2}{F}\Phi^2 \frac{R_d}{R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

and

$$b = \left(\frac{p}{3\,000} \cdot \frac{X_1}{R_1}\right)^2 \quad . \quad . \quad . \quad . \quad (16)$$

and the result is a simplified expression for the characteristic, namely

$$P = \frac{an}{1 + bn^2} \quad . \quad . \quad . \quad . \quad (17)$$

General Discussion

For convenience of discussion we shall plot the function given by (17), taking P for abscissae and n for ordinates. As shown in Figs. 5 and 6, the curve passes through the origin and has a vertical tangent at the point M, where P reaches a maximum value. The curve then approaches the vertical axis of co-ordinates asymptotically for rising values of n.

For very small speeds n, the characteristic is given by

$$P = an \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which is the expression for the baseline mentioned previously. The performance of the meter is then the same as would result if a standard non-reactive brake with an ohmic resistance equal to R_1 were used.

The value b determining the curvature of the characteristic, as given by (16), depends on the number of pole-pairs (p) and on the ratio of the reduced stray reactance to the ohmic resistance (X_1/R_1). The number of pole-pairs (p) is equal, in the case of the fundamental sine wave, to the number of rotor vanes. An increase of p means higher frequencies in the induced circuit, and consequently increased curvature at low speeds. The value of p is limited by constructional considerations relating to the space available for a sufficient number of slots and the value of the effective flux.

With regard to the ratio X_1/R_1, the stray inductance can be increased by providing a large number of deep and narrow slots in the stator. Iron closed paths of the stray lines could be adopted only if a nickel-iron alloy with constant initial permeability proved satisfactory. A further increase of the ratio X_1/R_1 can, however, be easily obtained by reducing the resistance R_1 to a

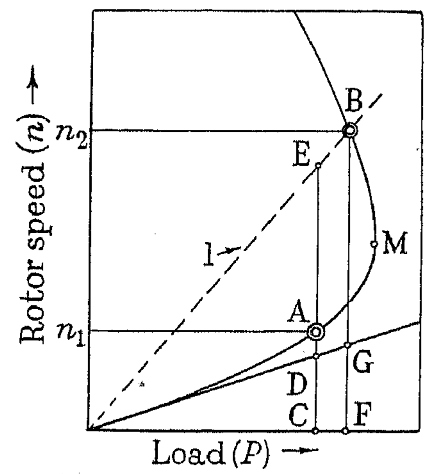


Fig. 5.—Construction of the characteristic for an elementary braking circuit.

minimum. The original limitations as to the weight of the eddy-current disc do not apply to a stationary secondary circuit, and the dimensions of the cage become merely a question of space available.

The point M corresponding to the maximum load is of particular importance in the determination of the constants, as it indicates the speed above which the meter

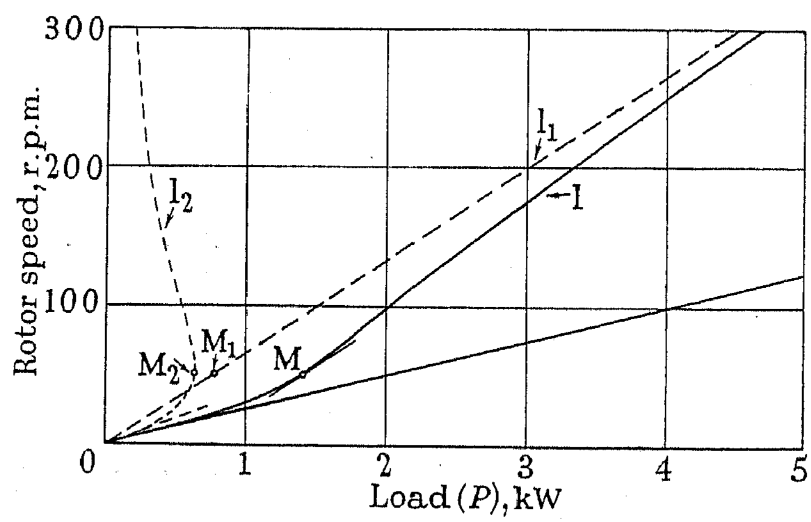


Fig. 6.—Superimposing of elementary characteristics.

would run away. Physically it is equivalent to the stalling point of the induction motor referred to above. The ordinate for P_{max} follows from (17) by putting $dP/dn = 0$, and its value is

$$n_M = \frac{1}{\sqrt{b}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

The maximum value of the load is then

$$P_{max} = a\,\frac{n_M}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

which means, referring to Fig. 5, that the baseline halves the ordinate of the point M.

Graphical Determination

Expression (17), when written in the form

$$n = \frac{1}{a}P + \frac{1}{a}P \,.\, bn^2 \quad . \quad . \quad . \quad . \quad (21)$$

leads to a useful graphical construction of the elementary characteristic.

Referring to Fig. 5, the point A has the co-ordinates $P_1 = \mathrm{OC}$ and $n_1 = \mathrm{CA}$. The distance CA can be broken up into two components CD and DA which would represent the two terms of expression (21); CD being the ordinate of the straight baseline. A second point B on the curve has the co-ordinates P_2 and n_2, and the respective components of n_2 are FG and GB. From the above it follows that

$$\frac{\mathrm{DA}}{\mathrm{GB}} = \frac{P_1 n_1^2}{P_2 n_2^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

which may be written

$$\frac{\mathrm{DA} \cdot \dfrac{n_2^2}{n_1^2}}{P_1} = \frac{\mathrm{GB}}{P_2} \quad . \quad . \quad . \quad . \quad . \quad (23)$$

This enables us to find the point B geometrically, when n_2 is given: On the ordinate of the point A fix a point E at a distance

$$\mathrm{DE} = \mathrm{DA} \cdot \frac{n_2^2}{n_1^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

Through this point E and the origin draw a straight line l; the point B lies on this line l and its ordinate is n_2.

(6) COMPOSITE BRAKING CIRCUITS

In cases where the performance curve of an elementary braking circuit does not suit the practical requirements, its shape can be varied by combining different braking circuits in the same meter.

In view of the fact that the measured load P is linear in relation to the braking torque [see (13) and (14)], we can superimpose the individual values of T_b, as if several independent braking elements were working on the common meter spindle. Thus

$$T_b = T_{b1} + T_{b2} + \ldots T_{b_n} \quad . \quad . \quad (25)$$

For calculation purposes it appears then convenient to split the load P also into the corresponding components

$$P = P_1 + P_2 + \ldots P_n \quad . \quad . \quad . \quad (26)$$

so that the entire meter can be treated as an assembly of component systems with different speed characteristics.

The superimposing of the values of P can conveniently be done graphically, as shown in Fig. 6. The graph shows a system consisting of a straight line and a reactive component, l_1 and l_2; the resultant line l is obtained by adding the corresponding abscissae of the components.

The slope of the resulting curve is then equal to the sum of the slopes of the components. Thus

$$\frac{dP}{dn} = \frac{dP_1}{dn} + \frac{dP_2}{dn} + \ldots + \frac{dP_n}{dn} \quad . \quad . \quad (27)$$

which facilitates the plotting of the characteristic. Referring to Fig. 6, it follows from $dP_2/dn = 0$ at the point M_2, that the tangent at the point M is parallel to the straight-line component. The resultant curve then passes through a point of inflexion the position of which is determined by the form of the reactive component. From that point on, the resultant curve approaches the straight line asymptotically. Since the sum

$$\frac{dP_1}{dn} + \frac{dP_2}{dn}$$

remains always larger than zero, the characteristic possesses no "runaway" point.

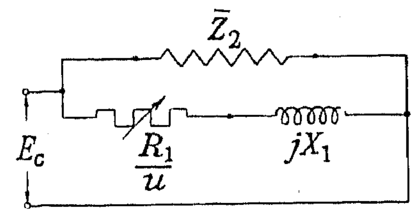


Fig. 7.—Equivalent diagram for a composite braking circuit.

The various braking systems can be combined in practice by adding a standard brake to the reactive braking element; this brake acting on the eddy-current driving disc. Another method is to provide two separate short-circuit cages in the bottom pole-piece of the modified brake; in this connection the experience which has been obtained with high-torque squirrel-cage motors will be found valuable.

In the equivalent circuit diagram every additional cage can be regarded as a shunt impedance connected to the supply terminals (Fig. 7). The circuit does not contain any series impedances before the shunt combination, a fact which agrees with our assumption that the currents and torques of the component systems are independent and can be calculated separately.

For a combination like that shown in Fig. 6, the additional impedance Z_2 consists of an ohmic resistance R_2/u only. The expression for the speed characteristic is then, referring to (17) and (26),

$$P = n\left(\frac{a}{1 + bn^2} + c\right) \quad . \quad . \quad . \quad (28)$$

In this equation c is proportional to the ratio R_d/R_2, where R_2 denotes the resistance of the straight-line circuit. The three parameters included in (28) indicate that, in addition to the baseline, two points on the resultant curve are required to determine the components of a characteristic. This offers ample possibilities for varying the features of a system.

This type of composite braking system is illustrated by the curves in Fig. 1. The appropriate constants, for a 4-vane rotor, are given in Table 1.

Table 1

CONSTANTS FOR THE CHARACTERISTICS GIVEN IN FIG. 1

Example	Constants			
	a	b	X_1/R_1	c
	kW-min.	(min.)^2		kW-min.
A	0·04	—	0	—
B	0·04	1/40000	3·75	—
C	0·03	1/15600	6·0	0·01
D	0·025	1/2500	15·0	0·015

(7) INFLUENCE OF FIELD HARMONICS ON THE PERFORMANCE

In all the questions dealt with so far, a sinusoidal field has been assumed. When the magnetic distribution is materially different from a sine wave, the actual characteristics deviate from the curves to which attention has been drawn above, and the methods of the Fourier analysis have to be adopted.

If we resolve the field into its harmonic components, the resultant torque of the brake will be equal to the sum of the component torques due to the harmonic waves of the field. The straight baseline found for the fundamental sine wave is also a straight line for the resultant field, the resultant parameter (a') assuming different values for each field form (see Appendix 1). The influence of the harmonic components on the parameter b, however, varies, owing to the value X' of the stray reactance contained in it. The expression for the characteristic must therefore be given by a Fourier series, as shown in equation (40), Appendix 1, and the curve calculated point by point.

Fig. 8 shows the results of tests analysed as indicated above. The arrangement of the braking element used was similar to that shown in Fig. 2; the rotor consisted of a flat 4-vane disc mounted on a shaft, which also carried the disc of a standard driving element; the lower pole-piece of the magnet was of annealed mild steel, provided with deep slots, at the bottom of which lay a copper cage; the ratio X_1/R_1 of the braking circuit was equal to 3·6. The meter was provided with a relatively small series field, so that the retarding torque of the series field could be neglected.

An auxiliary test proved that the component torque originating from eddy currents in the two moving discs and in the solid-bottom pole-piece was linear in relation to the speed. The system could therefore be considered to be a composite circuit, of the type represented by equation (28). The slope $(a' + c')$ of the baseline, and the co-ordinates of two observed points, were assumed. After substituting these values in (40) the parameters a', b, and c' were calculated by a method of approximation. The values of a_1 and c_1 for the fundamental wave then followed from (38), Appendix 1; and the ratio X_1/R_1 given by (16) could be checked against the value obtained from the dimensions of the cage.

In order to obtain a better illustration of the influence of the field form on the characteristic, those elementary curves should be found which have a common baseline of slope a' and pass through the individual performance points. The family of these "equivalent elementary curves" is given by

$$P = \frac{a'n}{1 + b'n^2} + c' \quad . \quad . \quad . \quad (29)$$

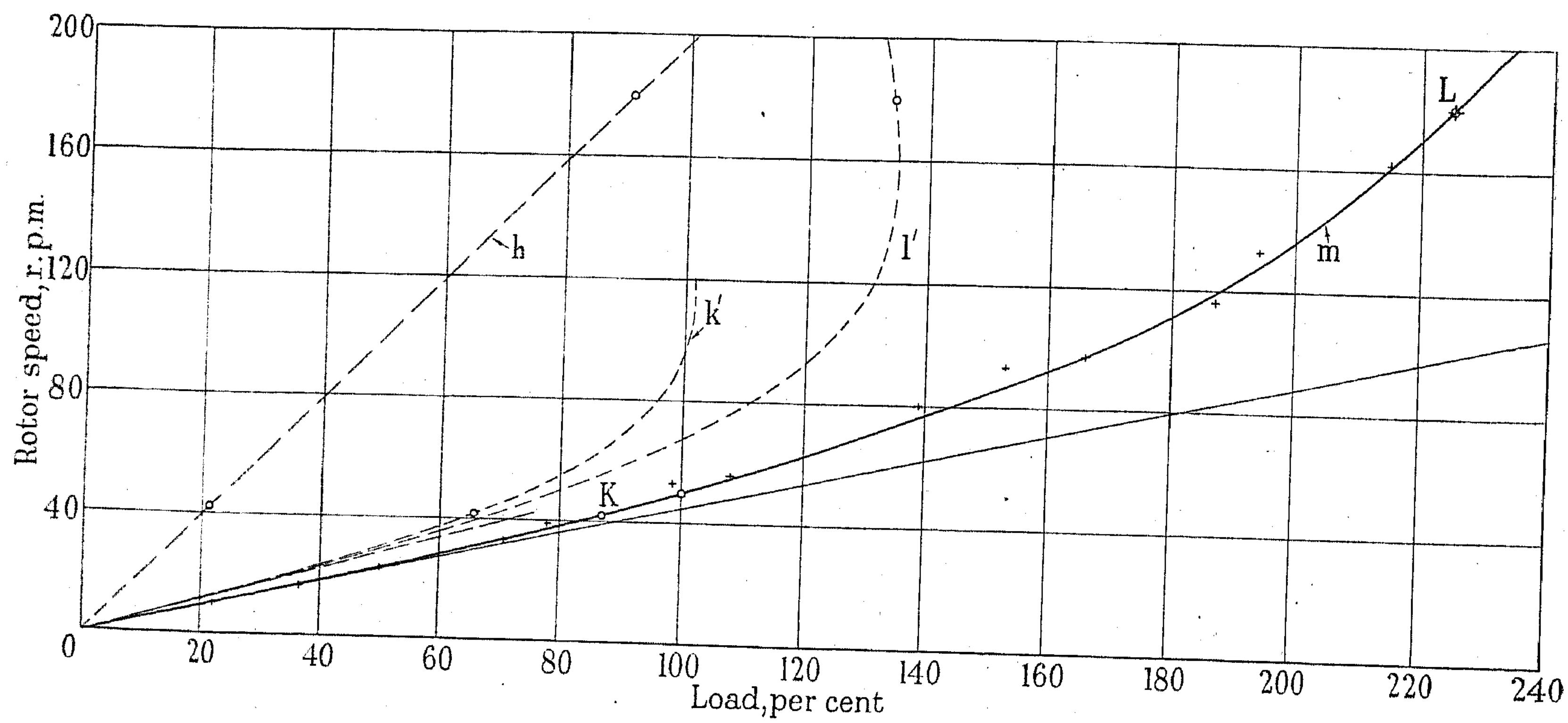


Fig. 8.—Influence of field harmonics.

+ + + Test points.
h Straight-line component.
k′, l′ Equivalent elementary curves for points K and L.
m Resultant characteristic.

In the above equation, a' and c' are the two known constants and b' is a variable parameter, which can be found by substituting in (29) the co-ordinates of the test points.

The two equivalent curves k' and l' given in Fig. 8 show that the value of b' decreases with rising speeds; which means that the influence of the higher harmonics on the curvature of the characteristic is weakened with the increase of the frequency. This fact is of practical importance and will be utilized in the design of the meter.

(8) CHOICE OF THE CHARACTERISTIC

In order to compare the features of the various speed characteristics given in Fig. 1, the speeds were plotted in Fig. 9 against the load expressed as a percentage of full load. The marked speed (n) was assumed equal to 50 r.p.m.

All the curves now pass through a common point at full

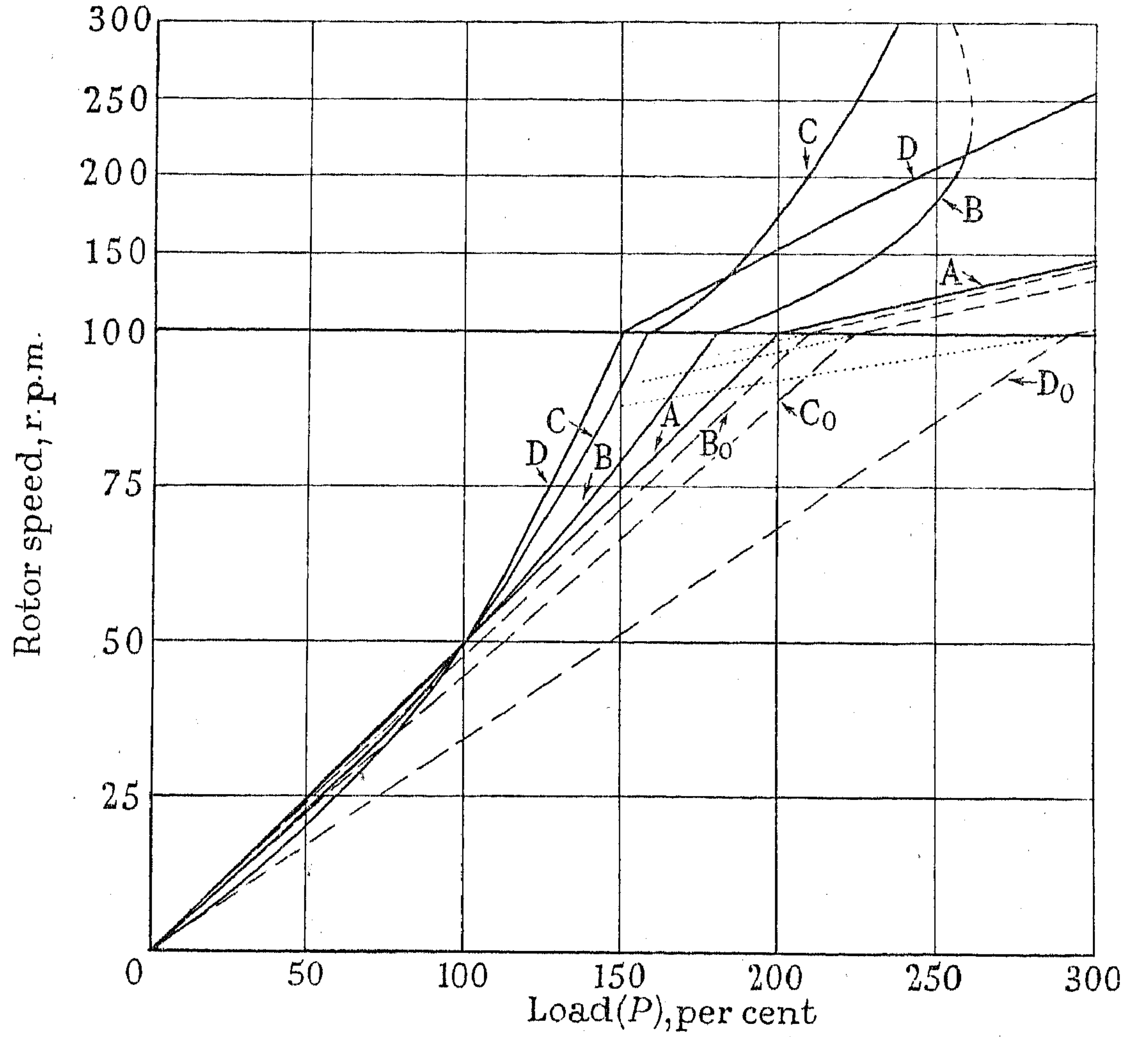


Fig. 9.—Load/speed curves. (Load expressed as percentage of full load.)

load, and their baselines show different slopes. In the normal working range, Curve D is the lowest; at overloads up to about $P = 180$ % it is the highest; farther on, however, it is intersected by Curves C and B, which have greater slopes for these speeds. Curve B reaches its "runaway" point at a load of 260 %, i.e. a speed of 250 r.p.m., and the corresponding meter would have to be electrically or mechanically protected in order not to exceed these values.

Table 2

SPEED-INCREASE FACTORS AT VARIOUS LOADS, EXPRESSED AS PERCENTAGES OF FULL LOAD

Curve	Speed-increase factor at:— 50 % f.l.	100 % f.l.	150 % f.l.	200 % f.l.
A	1·00	1·00	1·00	1·00
B	1·02	1·04	1·10	1·22
C	1·03	1·12	1·36	2·00
D	1·17	1·46	1·93	2·27

The speed-increase factors of these characteristics are given in Table 2. According to this Table the speed-increase factor for Curve B, at double full load, is 1·22 only, despite the fact that farther on the characteristic rises rapidly up to the "runaway" point. On the other hand, the rate-increase factors for Curves C and D at double full load are 2·00 and 2·27 respectively. The main difference between C and D is that at full load the rate-increase factor for C is only 1·12, whereas for D it is 1·46.

Load/speed curves give the relative price of the total watts consumed during the unit of time, at a given load. By differentiating these curves graphically we find the law defining the price of the watt-hour as a function of the load.

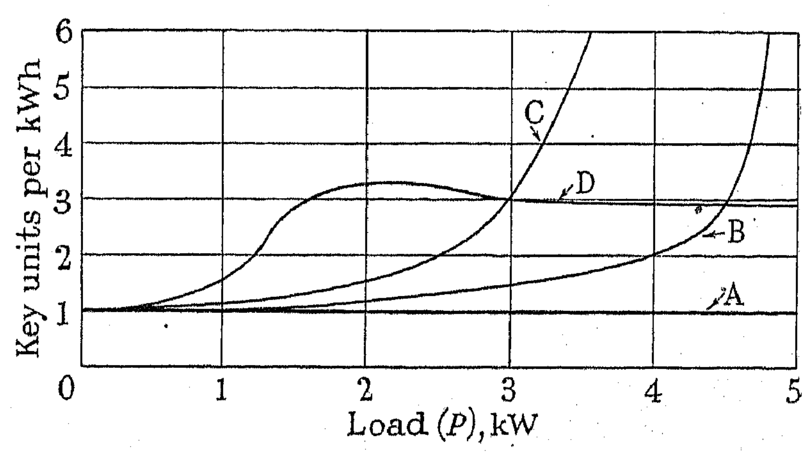


Fig. 10.—Price per unit, as a function of the load.

Such price curves have been derived for the examples A to D and are shown in Fig. 10, the ordinates being given in key units per kWh. The straight line A indicates a constant price per unit, which is independent of the demand. Curve B shows, at first, slight price-increases; it then rises suddenly in the vicinity of the P_{max} point. Line C illustrates a gradual change-over from a constant price to a rising rate. This rate is approximately proportional to the number of kilowatts in

excess of a certain basic demand value. According to line D the tariff works with two nearly constant rates, rather as in peak-load meters, but with the difference that the change-over from one rate to the other is here effected gradually by means of an intermediate curve.

All of the above curves have, as a common feature, a horizontal tangent at zero load, corresponding to the straight baseline of the speed characteristics. This is very convenient, as it enables us to introduce into the tariffs the influence of the diversity factors. At small demands, when the diversity is high, the rates can be kept at the level of the running charges only; whereas with rising loads the demand charges can be gradually superimposed according to a predetermined law.

The form of Curve D in Fig. 10 requires special consideration. It shows at the beginning of the higher rate a hump with a maximum value which, though relatively small, could not be permitted under a reasonable price law. This maximum point corresponds to the hardly discernible point of inflexion of the load/speed curve illustrated in Fig. 6. It is obvious that such maxima should be reduced or altogether eliminated from the normal working range of the meter.

The presence of a non-sinusoidal field in the brake offers a solution to this problem. The equivalent parameters b', mentioned above, decrease with rising speeds, which results in the shifting of the point of inflexion of the equivalent curves to higher values of the speed. The hump of the price curve can thus be eliminated from the working range, in spite of the pronounced curvature at low demands.

The value of the marked speed is of primary importance in the design of the proposed brake. In the above examples a speed of 50 r.p.m. was assumed, and this is the maximum permitted by the British Standard Specification. Actually, the marked speeds of modern watt-hour meters are much lower than this value, the purpose being mainly to reduce the negative overload error of the driving element. This factor need not be taken into account in the new meter, because of the altered shape of the characteristic.

(9) BALANCING AND ADJUSTING THE METER

The magnetic system of the meter must be well balanced in order to avoid unsymmetrical forces on the iron disc. In addition to the standard dynamic test the rotor will have to pass a magnetic test on a calibrated bench provided with a symmetrical field distribution. Suitable means must be devised also for the adjustment of the field symmetry in the stator.

The use of a spherical braking disc, of the type shown in Fig. 2, facilitates the balancing of the stator. The moving element has then a position of stable equilibrium for any distribution of the stationary field and, if supported freely, will assume various positions according to the variation of the field form. For testing purposes the free support can be secured by providing an open spherical cup bearing in place of the bottom jewel.

Fig. 11 illustrates the forces in a balanced system when the rotor is displaced from its equilibrium position. The moving element, the supporting surface A, and the top bearing B, are shown diagrammatically. P_1 is the force acting on the upper surface of the disc; P_2 and P_3 are the resultants of the unsymmetrical forces acting on the lower surface (shown exaggerated). The lines of action of all the magnetic forces pass through the centre C of the concentric spheres on which the surfaces of the disc lie. The resultant P_r of these magnetic forces combined with the weight of the rotor G produces the force Q. This force Q gives the bearing reactions R_1 and R_2 and a moment about the point B which tends to bring the rotor back to its central position. Since in practice the component forces of the diagram are nearly parallel to

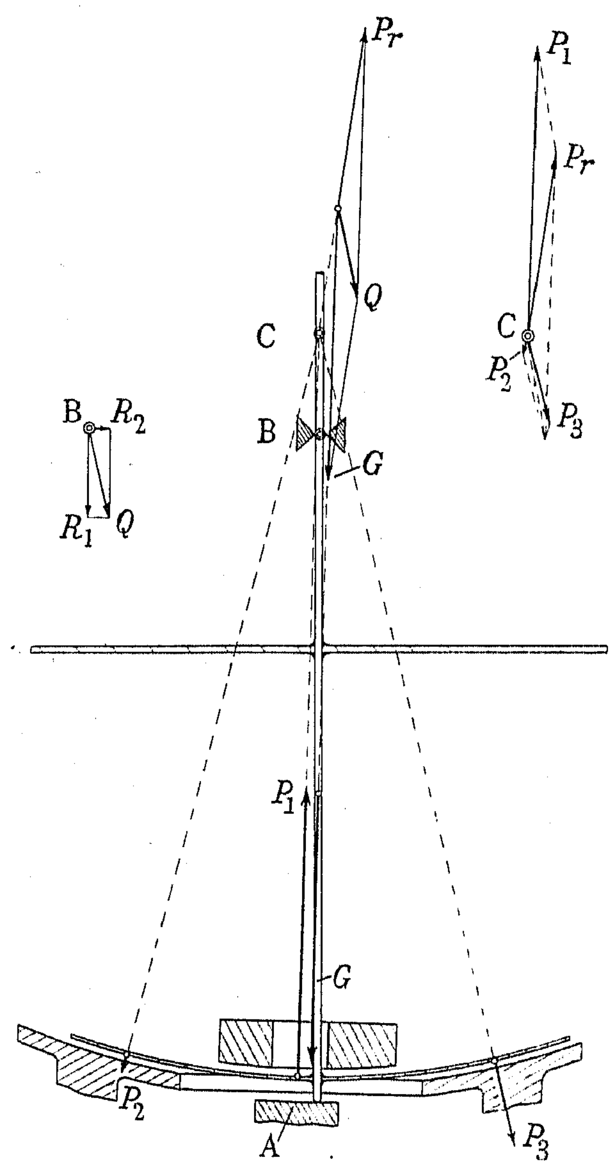


Fig. 11.—Mechanical balance of the rotor.
(Not to scale.)

each other, the stabilizing torque must be found by calculation.

The diagram shows that a braking disc of small diameter and low centre of gravity will increase the stability of the moving system. The distance between the centre C of the spheres and the top bearing B is essential for producing a stabilizing torque; however, it should not be made too large, because if this is done the radial movement of the rotor becomes eccentric, and this is likely to cause excessive variation of the air-gaps.

In view of the fact that the moving system is self-aligning and magnetically floated, the bearing pressures are small. Furthermore, the rotor is not subject to side thrust resulting from the retarding torque, as in the existing types of eddy-current brakes.

The speed of the meter has to be adjusted in accord-

ance with the equations of the characteristic. With composite braking systems, as dealt with in (28), a minimum of three test points is required for the calibration, and it is practically sufficient to adjust only the intensity of the fluxes passing through the reactive system and the driving disc. In cases where no braking flux passes through the driving disc, a small variable-shunt flux should be provided for calibration purposes. When essential alterations of the characteristic are required in special cases, the leakage inductance of the system, i.e. the parameter b, can be varied by means of an adjustable iron bush fitted over the end-rings of the bottom cage.

When comparing the accuracy of the device with that of the standard watt-hour meter, the additional errors due to the modified braking element must be taken into consideration. These errors may have their source in the magnetic features of the circuit, in a lack of mechanical stability, or in the temperature coefficients of the ohmic resistances.

In view of the fact that the flux passing through the permanent magnet remains practically constant, the magnetic conditions in the brake can be considered to be the same as in the existing types. The mechanical stability of the moving system in the new arrangement is worse than in the standard meter, but the difficulties can be overcome as explained above. The temperature coefficient remains the only important source of error, and will be considered below.

It should be noted, as an advantage of the reactive braking element, that it provides compensation of the driving-torque error at overloads. Furthermore, the system with a curved characteristic provides at low speeds a considerably greater torque than an equivalent standard meter of the same rated speed.

(10) THE TEMPERATURE ERROR

In all the above expressions for the characteristic, constant values of the resistances have been assumed. For varying temperatures the values of the resistances also vary; and for a temperature-difference of τ deg. C., equation (28) becomes

$$P_\tau = n\left(\frac{a_\tau}{1 + b_\tau n^2} + c_\tau\right) \quad . \quad . \quad . \quad (30)$$

where a_τ, b_τ, and c_τ denote the values of the parameters a, b, and c at the new temperature (see Appendix 2).

For equal temperature coefficients, $\alpha_d = \alpha_1 = \alpha_2$, and for small speeds n the expression (30) becomes independent of the temperature. This agrees with the known fact that in a standard meter the temperature errors of the driving and braking torques compensate one another.

At higher speeds, however, the load P_τ varies considerably with the temperature, and for very large values of n it becomes proportional to the square of the factor $(1 + \alpha\tau)$. This increase of P_τ with rising temperature can be explained as follows: When the resistance R_1 of the reactive braking circuit is increased, the power factor alone of the induced currents is altered, while the intensity of these currents remains nearly unchanged, and the result is a greater retarding torque. The eddy currents, however, of the purely ohmic circuit in the driving disc are inversely proportional to the resistance R_d, and any increase of R_d means a reduction of the driving torque. Therefore the effects of temperature-changes on the driving and the braking torques are in the same direction, and do not compensate one another as in the standard meter.

From the above consideration there follows a method for the inherent compensation of the temperature error.

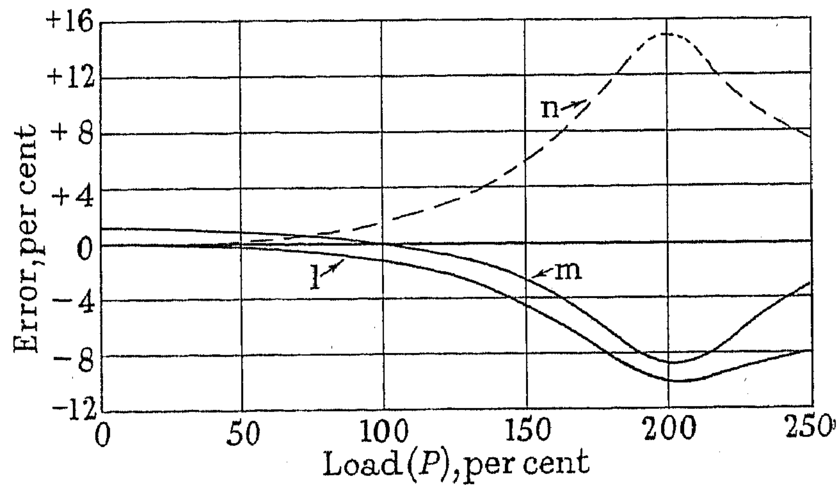


Fig. 12.—Temperature errors of meter Type C.

Curve l : for $\tau = +15°$ C. and $\alpha_d = \alpha_1 = \alpha_2$.
Curve m: for $\tau = +15°$ C. and $\alpha_d = 0{\cdot}81\alpha_1$; $\alpha_1 = \alpha_2$.
Curve n : for $\tau = -15°$ C. and $\alpha_d = \alpha_1 = \alpha_2$.

The materials for the resistances R_1 and R_2 should be so chosen that their temperature coefficients are higher than the coefficient of the resistance R_d of the driving disc. The straight-line torque will then decrease at higher temperatures and balance the torque-increase of the curved component. This is confirmed by expression (30), and the calculations in Appendix 2 prove that the method leads to practical results.

Figs. 12 and 13 show the temperature errors for the characteristics C and D. The errors are found from the differences of the rotor speeds, expressed as percentages, and have been calculated for temperature-differences of $\pm$ 15 deg. C. The graphs show that the errors vary with the loads and reach maximum values in the overload range of the meter. Curves l and n refer to cases where materials with equal temperature coefficients were used for the induced circuits of both the driving and the braking elements. Curves m give the results for inherent compensation.

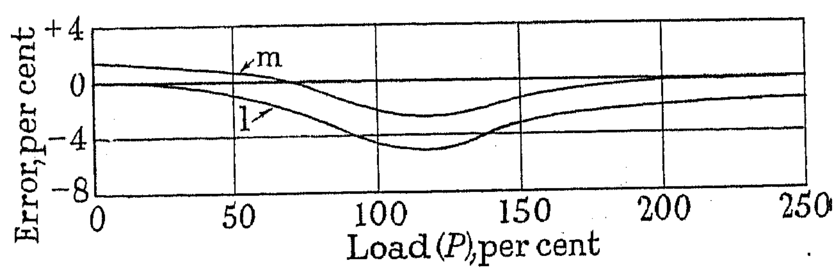


Fig. 13.—Temperature errors of meter Type D.

Curve l : for $\tau = +15°$ C. and $\alpha_d = \alpha_1 = \alpha_2$.
Curve m: for $\tau = +15°$ C. and $\alpha_d = 0{\cdot}71\alpha_1$; $\alpha_1 = \alpha_2$.

For the Type C meter perfect compensation is assumed at full load, and the maximum errors of the compensated curve are $+1{\cdot}3$ % at zero load and $-8{\cdot}7$ % at about double full load. Up to an overload of 30 % the error is less than $-1{\cdot}3$ %, which is regarded as the limit of the working range. Meter D is assumed to be perfectly compensated at a load of 70 %; its error curve shows a positive maximum of $+1{\cdot}5$ % at the starting point and a negative maximum of $-2{\cdot}5$ % at 17 % overload;

beyond this point the error decreases, until at 120 % overload its value is again zero. The overload characteristic of this meter is obviously very advantageous.

From Figs. 12 and 13 it follows that the temperature error can be kept small, either by moving its maximum point beyond the practical working range of the meter, as is done in Type C, or else by choosing a relatively small reactive component with a high ratio X_1/R_1, as in Type D. The effect of the compensation appears in the graph roughly as a parallel shifting of the error curve by an amount equal to the negative value of the ordinate at the point of complete compensation. The maximum error, and consequently also the nominal mean error, can be reduced in this way to about half their original values. Under practical conditions, however, the actual mean error is much smaller than the nominal mean error. This is due to the fact that the high values of the compensated-error curve lie at the extreme ends of the working range.

The nominal mean error of Curves C and D amounts to about $\pm 0{\cdot}9$ % for the practical working range of the meters and for temperature-differences of $+15$ deg. C. This is equivalent to a nominal temperature factor of less than $0{\cdot}06$ % per deg. C., independently of the power factor of the load and without any outside compensation.

(11) CONCLUSIONS

The device offers new facilities in the application of demand charges. It works on the same principle as a standard watt-hour meter and deviates from the latter only in regard to its speed characteristic.

The altered performance of the meter is obtained by providing stray reactance in the induced circuit of the magnetic brake. From the equation of the new performance curve it follows that a high ratio of the stray inductance to the resistance of the braking circuit is desirable, in order to meet practical tariff requirements and to improve the accuracy. By properly combining different braking circuits, adequate variation of the load/speed curves can be obtained.

The balancing and the calibration of the device are more elaborate than in the case of a standard watt-hour meter; the instrument is also more sensitive to rough handling; but, in comparison with maximum-demand indicators, the sliding-scale meter appears simpler, has smaller losses, and is more reliable in operation. It should be particularly suitable for use on networks where the load factor is bad, provided the claims put forward here are confirmed in practice.

Acknowledgment

The author wishes to express his thanks to Dr. F. Ollendorff for the keen interest he took in reading the manuscript of the paper, and for his helpful criticism.

APPENDIX 1

The Characteristic, Assuming a Non-Sinusoidal Field

If we resolve the field into its harmonic components expression (26) takes the form

$$p = \sum_{q=1}^{q=\infty} p_q \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

in which p indicates instantaneous values of the total load and p_q the instantaneous values of the components of the load corresponding to the harmonic components Φ_q of the braking flux.

If the instantaneous value p_q satisfies the equation

$$p_q = P_{q\,max} \cos^2 \omega t = 2P_{q\,eff.} \cos^2 \omega t \quad . \quad (32)$$

we obtain, by means of (14) and (16),

$$p_q = 2\,\frac{K_2}{F}\,\frac{R_d}{R_1}\,\Phi_q^2 n\,\frac{\cos^2 \omega t}{1 + q^2bn^2} \quad . \quad . \quad (33)$$

For a symmetrical rectangular field distribution the instantaneous values of the components are found from the Fourier series

$$\Phi_{inst.} = \Phi_1 \left(1 \cos \omega t - \frac{1}{3} \cos 3\omega t + \frac{1}{5} \cos 5\omega t \pm \ldots \frac{1}{q} \cos q\omega t\right) \quad . \quad . \quad (34)$$

The instantaneous values of the load are therefore

$$p = 2\,a_1 n \left[\frac{\cos^2 \omega t}{1 + bn^2} + \frac{\cos^2 3\omega t}{9(1 + 9bn^2)} + \frac{\cos^2 5\omega t}{25(1 + 25bn^2)} + \ldots\right] \quad . \quad (35)$$

where

$$a_1 = \frac{K_2}{F} \cdot \frac{R_d}{R_1} \cdot \Phi_1^2 \quad . \quad . \quad . \quad . \quad (36)$$

and the effective value of the load is given by

$$P = a_1 n \left[\frac{1}{1 + bn^2} + \frac{1}{9(1 + 9bn^2)} + \frac{1}{25(1 + 25bn^2)} + \ldots\right] \quad . \quad . \quad (37)$$

At very small speeds (n) the series in the brackets assumes the value $\pi^2/8$, and (37) reads

$$P' = \frac{\pi^2}{8} a_1 n = a'n \quad . \quad . \quad . \quad . \quad (38)$$

and, if referring to (36), (15) and (18), we have

$$P = \frac{\pi^2}{8} P_1 \quad . \quad . \quad . \quad . \quad . \quad (39)$$

This is the equation to the baseline of the characteristic for a symmetrical rectangular field. The expression shows that the load P is $\pi^2/8 = 1{\cdot}23$ times greater than the load P_1 due to the fundamental wave. The same ratio applies also to the torques. This agrees with the result obtained by calculating the torque directly from the currents induced in the cage by a rotating field of constant intensity.

After substituting for a_1 in (37) the value found experimentally from (38), we arrive at the general equation of the characteristic for a symmetrical rectangular field, namely

$$P = \frac{8}{\pi^2} a'n \sum_{q=1}^{q=\infty} \frac{1}{q^2(1 + q^2bn^2)} \quad . \quad . \quad (40)$$

in which q denotes all the odd integers.

APPENDIX 2

Calculation of Temperature Errors

For a temperature-difference of τ deg. C. the temperature error is given by

$$y = \frac{n_\tau - n}{n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

From this it follows that

$$n_\tau = n(1 + y) \quad . \quad . \quad . \quad . \quad . \quad (42)$$

With α_d, α_1 and α_2 denoting the temperature coefficients of the materials used for the resistances R_d, R_1 and R_2, the parameters a, b, and c assume the values

$$a_\tau = a\frac{1 + \alpha_d\tau}{1 + \alpha_1\tau} \quad . \quad . \quad . \quad . \quad . \quad (43)$$

$$b_\tau = b\frac{1}{(1 + \alpha_1\tau)^2} \quad . \quad . \quad . \quad . \quad . \quad (44)$$

$$c_\tau = c\frac{1 + \alpha_d\tau}{1 + \alpha_2\tau} \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

Assuming that the load remains unaltered for both values of the speed, i.e. $P = P_\tau$, we obtain, for the composite system given by (28) and (30), the basic equation

$$n\left(\frac{a}{1 + bn^2} + c\right) = n(1 + y)\left[\frac{a_\tau}{1 + b_\tau n^2(1 + y)^2} + c_\tau\right] \quad . \quad . \quad . \quad (46)$$

From which the temperature error y can be found.

If we neglect the higher powers of y, the above equation can be reduced to the form $y = f(n)$; and by introducing the numerical values of the parameters a, a_τ, b, b_τ, c and c_τ of a particular meter we arrive at the equation to the error curve. These equations do not show the error as proportional to the temperature.

Curves l and n in Figs. 12 and 13 were derived in this way for a meter in which the temperature coefficients α_d, α_1 and α_2 were equal.

For perfect compensation at a given speed n the error y becomes zero, and the equation obtained thus from the function $y = f(n)$ can be used for determining the value of one of the three parameters a_τ, b_τ or c_τ.

As an example, let the reactive cage of the brake consist of a material having a greater temperature coefficient than that of the driving disc; and let the straight-line component originate from eddy currents in the driving disc. This may be expressed by

$$\alpha_1 > \alpha_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

$$\alpha_2 = \alpha_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

from which it follows that

$$c_\tau = c \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

The temperature coefficients must then fulfil the following condition:—

$$\frac{\alpha_d}{\alpha_1} = \frac{1 - bn^2}{1 + bn^2} \quad . \quad . \quad . \quad . \quad (50)$$

Applying this equation to Example C, and assuming perfect compensation at $n = 50$ r.p.m., we get $\alpha_d/\alpha_1 = 0{\cdot}72$.

A greater value of α_d/α_1 is obtained when the non-inductive circuit of the brake is assumed to consist of a second cage placed in the lower pole-piece at the open end of the slots. Both the reactive and the non-reactive cages can then be made of the same material. The conditions for the temperature coefficients are now

$$\alpha_1 > \alpha_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

$$\alpha_2 = \alpha_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

The ratio α_d/α_1 can now be derived by a procedure similar to that used before. For compensation at $n = 50$ r.p.m. (see Fig. 12), $\alpha_d/\alpha_1 = 0{\cdot}81$. This value can be obtained by using copper for the braking cages and an aluminium-copper or aluminium-silver alloy for the driving disc. The ratio α_d/α_1 reaches a minimum value of $0{\cdot}33$ for $n = 177$ r.p.m. This speed is in the immediate vicinity of 184 r.p.m., which is the speed corresponding to the maximum point of the error curve.

For Example D in Fig. 13, using the same method, we find $\alpha_d/\alpha_1 = 0{\cdot}71$.

In the above calculations the effect of the temperature on the intensity of the eddy currents induced outside the braking cages is neglected.

DISCUSSION ON

"AN EXPERIMENT ON ELECTROMAGNETIC INDUCTION BY LINEAR MOTION"*

Mr. G. H. Rawcliffe (*communicated*): The paper is of interest to me as I followed closely the controversy between the late Prof. Cramp and Prof. Howe,† arising out of Prof. Cramp's paper, to which reference is made.‡ When theory leads to a slightly surprising conclusion it is always reassuring to put it to proof, but, in suggesting that this experiment might assist in "the correct formulation of the laws of electromagnetic induction," I think that the author may be guilty of what Prof. Howe has called "chimera chasing." He concludes that "the experiment does not provide a means of proving either the Maxwell–Lorentz theory or the moving-field theory to be incorrect." No: and surely no experiment ever could do this. Since lines of force are arbitrary conventions, it is idle to try to determine their properties by experiment.

I doubt whether it is true that "both flux-cutting and flux-linking laws must be used" with the fixed-field theory. The linkage law seems to me to comprehend the cutting law; if a line of force cuts into a circuit it will, in general, link it after doing so. Further, where cutting takes place without alteration of linkages no e.m.f. is induced. A peculiar homopolar construction exemplifying this is given by Dunton.§ The cutting law does not, however, comprehend the linkage law, and a pure cutting theory makes it hard to see why any transformer ever works.

The apparently paradoxical result of this experiment arises from the amalgamation of parts of the magnetic circuit being linked and the electric circuit linking it. Since the electric circuit is continuously changing, it is necessary to consider instantaneous rates of change of magnetic state, rather than the difference of magnetic state before and after a short interval of time, δt.

Moving field or fixed field: flux linkages or flux cuttings: which are correct? These are questions which ought never to be asked because they can never be answered. The author suggests that answers might be forthcoming, and then admits that his experiment does not provide them. Might it not be well to emphasize that whatever this and similar experiments may do, they cannot answer these questions?

Prof. E. G. Cullwick (*in reply*): The purpose of the experiment described in my paper was not to determine any properties of "lines of force," but to establish a simple experimental fact. Any theory of electromagnetic induction must be consistent with this fact, and to my mind both the Maxwell–Lorentz theory and what I call the "moving field" theory satisfy this condition, provided they are properly applied. My justification for performing the experiment is that statements of the laws of electromagnetic induction found in many textbooks are not consistent with the result.

The two alternative theories give identical results for all cases of closed circuits: therefore no experiment on a closed circuit can prove either to be incorrect. It also appears to me that the same applies to all open-circuit experiments on conducting magnets, a problem which I have examined in some detail elsewhere.† The two theories, however, are not equivalent for magnetic *insulators* unless the Maxwell–Lorentz (fixed field) theory is modified in a manner which appears to fail in logical consistency.‡ Since such cases are outside the range of engineering experience it follows that engineers may use either theory, provided they use it correctly.

The "peculiar homopolar construction" mentioned by Mr. Rawcliffe is evidently the machine described by Dr. A. E. Clayton in 1915.§ It is in fact an excellent example of the truth of my statement that "both flux-cutting and flux-linking laws must be used with the fixed-field theory." The correct explanation of the negative behaviour of this machine, by the orthodox Maxwell–Lorentz theory, has been given by Prof. Howe.‖ This explanation is somewhat complex, and a much simpler one is provided by the moving-field theory as explained in my paper. The resultant magnetic field of the machine is split into two components: one due to the rotor iron which is considered to rotate with the rotor, and one due to the stationary field coils and stator iron which is considered to be stationary. Apart from any small cyclic variation of these components owing to the varying relative positions of stator and rotor yokes during rotation, they are *separately* constant and unchanging relative to their respective sources. However, owing to the changing relative positions of their configurations, the *resultant* field at any stationary point in or near the rotor iron will change periodically during rotation. The only possible cause of a unidirectional e.m.f., by the moving-field theory, is the motion of the rotor coils through the stationary stator-component of the field, and this is easily seen to give zero e.m.f.

Dunton¶ has recently claimed that the machine disproves the *BLI* law of force for a current-carrying conductor, but that this is not so has been shown by Prof. Howe.** The explanation lies in the fact that the

* Paper by Prof. E. G. CULLWICK (see *Journal I.E.E.*, 1939, **85**, p. 315).
† *Electrician*, 1936, **117**, pp. 191, 464, 493, and 625.
‡ W. CRAMP and E. H. NORGROVE: "Some Investigations of the Axial Spin of a Magnet," *Journal I.E.E.*, 1936, **78**, p. 481, and (Discussion) 1936, **79**, p. 344.
§ "Validity of Laws of Electrodynamics," *Nature*, 1937, **140**, p. 245, also quoting A. E. CLAYTON, *Electrician*, 1915, **75**, p. 481.

† "The Fundamentals of Electro-Magnetism" (Cambridge University Press, 1939), p. 321.
‡ *Ibid.*, p. 118.
§ *Electrician*, 1915, **75**, p. 481.
‖ *Electrical Review*, 1935, **116**, p. 598.
¶ *Nature*, 1937, **140**, p. 245.
** *Loc. cit.*

reaction of the forces experienced by the rotor coils is shared between rotor and stator. It may easily be seen that no torque results from the flow of armature currents in the stator component of field, so that the reaction on the stator is zero. The stator component of field tends to make the armature coils twist on the rotor iron, while the rotor component of field tends to make the coils slide along the rotor iron. The reaction of the tangential forces on the coils is borne entirely by the rotor, and, as Prof. Howe happily puts it in the letter to which reference has been made, " The fact that the man who tries to hoist himself by means of his own braces does not move is no proof that he is not exerting a force on his braces."

It is generally accepted that Faraday's disc is an example of electromagnetic induction in which " cutting takes place without alteration of linkages."

The result of this experiment appears paradoxical only in relation to the incomplete statement of the laws of induction found far too often in our textbooks.

INSTITUTION NOTES

INAUGURATION OF SESSION 1939–1940

At the opening meeting of the Session, which this year could not be held owing to the outbreak of war, the President, Mr. Johnstone Wright, would have delivered his Inaugural Address. The Address, copies of which were circulated in October to all members, appears on page 1 of this issue of the *Journal*.

The following appreciations of the retiring President and the new President have been received in place of those which would normally have been delivered at the opening meeting.

Dr. A. P. M. Fleming, C.B.E.
(Retiring President)

Mr. H. T. Young: For the first time—and, let us hope, the last—in the history of our Institution, war conditions have prevented the holding of the usual opening meeting to hear the Inaugural Address of a new President and to bid farewell to the retiring President. It has fallen to me to express the thanks of the members to Dr. Fleming for his services as President during the past year.

With our gratitude to him for his untiring labours there is mingled a special measure of sympathy. While it is true that the upheaval of war did not occur until Dr. Fleming's year of office was nearing its close, we all remember that the months preceding the war were marked by increasing tension and anxiety. Throughout this difficult period Dr. Fleming fulfilled all the normal duties of President with the greatest efficiency and kindliness, and also undertook many additional responsibilities incidental to our country's preparations for war, including the active representation of The Institution on the Ministry of Labour National Voluntary Register and its various Committees. Further, he had the task of selecting a successor to Mr. Rowell as Secretary, and of helping to initiate Mr. Brasher into his new duties.

In all these directions Dr. Fleming has been unsparing with his energy and uncompromising in his thoroughness. He has long been noted for his high conception of the functions of the engineer, and we on the Council have had ample occasion to realize, during the past year, that he himself is the best exponent of the exacting standards of service he has advocated. It is, therefore, with warm appreciation for the arduous work Dr. Fleming has done on our behalf that I conclude with the time-honoured formula: " That the best thanks of The Institution be accorded to Dr. A. P. M. Fleming for the very able manner in which he has filled the office of President during the past year."

Mr. J. R. Beard: As Mr. Young has mentioned, Dr. Fleming has had a specially arduous year of office, since, in addition to fulfilling all the very exacting engagements which nowadays devolve on our President, he had the burden and anxiety of steering The Institution through the difficult period immediately preceding the war. We all remember especially his inspiring Presidential Address —delivered without a note—and the excellent organization of our Summer Meeting at his own North-Western Centre. Although in the fullest sense a national figure—as evidenced by his election to the chairmanship of the Educational Section of the British Association—we like to remember him as a Past-Chairman of the North-Western Centre who has always had the welfare of our local Centres very much at heart. Mr. Young has referred to Dr. Fleming's work for The Institution in connection with the National Register set up by the Ministry of Labour. As one who took a considerable part in this work I can testify to the very valuable advice and guidance which Dr. Fleming was able to give at the critical early stages in the organization of the Register, valuable not only to our own Institution but also to the Government and to all the technical organizations associated with the work.

In Dr. Fleming we have a notable addition to our distinguished roll of Past-Presidents, and we would wish him to know that he joins it with the Institution's appreciation not only of the able way in which he filled the normal duties of President but also of his work in one of the most critical periods through which our country has had to pass. We all hope that as a younger " elder statesman " we may have for very many years to come the benefit of his knowledge and experience.

Johnstone Wright
(President)

Mr. J. S. Highfield: I have very great pleasure in writing about our President who has taken the helm in these critical times when Britain, with her good Allies,

strives once more for liberty—the most precious possession of all. I am sure we feel what an extra burden the state of war throws upon him. At the same time, he is deprived of many opportunities of personal contact with our members which, in my own experience, was a source of never-ending pleasure. I hope—we all hope—that events will restore to him these precious opportunities.

The President has presented a really classic Address on a subject all his own; he relates with singular clarity the problems involved and the methods used in the construction of the engineering work designed for the supply of electricity, commonly known as the "Grid." What an inadequate and yet characteristic name for so great a work!

The writing of such a weighty Address, where no salient points are missed and where full information is given, is possible only when the author has complete mastery of his subject.

Starting with a graceful reference to the late Sir John Snell and to Sir Archibald Page's Presidential Address in 1927, he describes step by step the many technical problems which called for solution and the many works constructed to make up the whole electrical system which was from the first a great technical success and which for unity of design and construction cannot be rivalled. I am sure that every member will appreciate his Conclusion. It expresses a note of tolerance; it is a noble witness to the value of honest, unselfish work. It is true that the co-operative spirit prevailing in the supply industry has enabled a worthy end to be attained.

I am sure I express the desire of our many members in thanking the President for his Address and in wishing him well during his term of office in these exacting yet inspiring times.

Sir Noel Ashbridge: I feel it a great honour to be adding a few remarks to what Mr. Highfield has written on the inauguration of our new President. It requires very little imagination to appreciate how great must be the load which rests on the shoulders of anyone who occupies Mr. Johnstone Wright's position—a heavy responsibility in peace time but in war time almost overpowering. Nevertheless, he has now shouldered the burden of directing the affairs of our Institution in circumstances which must greatly increase the difficulties of this task, anxious, as I know he is, to continue the Institution's work to the greatest possible extent, while at the same time extending it to meet any special emergencies that may arise. Few Presidents have been faced with the task of writing an Address at a time when this country hung between peace and war; at a time, in fact, when no-one knew whether The Institution would be able to carry on its work at the time fixed for the inaugural meeting.

In spite of this we have an outstanding contribution which will remain of permanent value to the industry, and which will place on record an achievement that, unfortunately, is not widely enough appreciated outside the profession. It is greatly to be regretted that we have not had the advantage of hearing it read at an inaugural meeting.

In conclusion I cannot refrain from expressing the hope that before our new President completes his term of office peace may at least be in sight.

ACTIVITIES OF THE INSTITUTION

The following is a copy of the circular letter which was enclosed with the December issue of the *Journal* to every member:—

15th December, 1939.

Dear Sir,

Institution Activities

In accordance with the arrangement indicated in the circular letter of the 16th October the Council have now reviewed the position regarding the activities of The Institution during the second half of the Session.

In view of the fact that a definite desire had been expressed by some members for the resumption of meetings and that the conditions now prevailing are such that the arrangement of a programme and the actual holding of meetings would be practicable, the Council feel that the full extent of the Institution's activities should again be put into operation as far as circumstances will permit. They are satisfied that adequate air-raid shelter facilities are available in the Institution building and nearby, and they have accordingly resolved that the meetings of The Institution in London should be resumed during the second half of the Session if the present conditions continue. The above decision applies to the Ordinary Meetings, Informal Meetings, meetings of the three Technical Sections and of the London Students' Section. Programmes for each class of meeting are now being drawn up and details will be issued to all members in the usual form early in January. It will, of course, be understood that if present circumstances change it may be necessary to cancel the meetings at short notice, and arrangements are being made to advise members at once, if such cancellation proves to be necessary. The Council feel that it is undesirable, at any rate for the time being, to contemplate any resumption of the usual features of a social character such as the Annual Dinner, the Electrical Engineers' Ball, and Section Dinners. As regards activities in the provinces, the various Committees will decide in the light of local conditions whether they are able to carry out a programme of meetings, visits and functions, and details of such programmes as are arranged will be included as usual when the London programme is issued.

It is considered that the resumption of meetings will be of value not only from the technical point of view, but also as a means of renewing personal contacts with fellow members, and it is hoped that all members will help the Council in their endeavour to resume normal activities as far as possible.

The Ordinary Meetings and meetings of the Wireless and Transmission Sections will commence at 6 p.m. as usual, and the Meter and Instrument Section Meetings and Informal Meetings will also commence at that hour instead of at the customary hour of 7 p.m. These meetings will finish at approximately 8 p.m. so as to mitigate as far as possible the difficulties of curtailed transport facilities.

Ordinary Meeting, 11th January, 1940

A purely formal Ordinary Meeting will be held in the Lecture Theatre, Savoy Place, London, W.C.2, on Thursday, 11th January, 1940, at 12.30 p.m., for the

suspension of a list of names of applicants for election and transfer approved by the Council.

ORDINARY MEETING, 25TH JANUARY, 1940

The first Ordinary Meeting of the programme for the second half of the Session will take place on Thursday, 25th January, at 6 p.m., when a discussion on "Fire-fighting Equipment for Electrical Installations," based on the E.R.A. Report on this subject contained in the enclosed December number of the *Journal*, will be introduced by Messrs. H. W. Swann, J. Hacking and R. A. McMahon. Their introductory remarks will be illustrated by a cinematograph film in colour.

Yours faithfully,

W. K. BRASHER,

Secretary.

MEMBERS ON SERVICE WITH H.M. FORCES (SECOND LIST)*

(NOTE.—The Secretary will be glad to receive, for publication in subsequent lists, the names of other members of The Institution who are serving with His Majesty's Forces, together with particulars of their rank and the unit in which they are serving.

It is also proposed to publish lists of promotions, transfers, military honours awarded, etc. All such particulars, both in regard to a member himself and in connection with other members of whom he may have knowledge, should be sent to the Secretary as early as possible so that the Institution records can be kept up to date.)

Members

Name	*Corps, etc.*	*Rank*
Barney, L. W.	Royal Air Force	Flt.-Lieut.
Beckett, C. M.	Royal Signals	Captain
Ferranti, V. Z. de	Royal Engineers	Major
Holt, F. B.	Auxiliary Air Force	Flt.-Lieut.
Jones, F.	Royal Engineers	Captain
Palmer, W. T.	Royal Signals	Lieutenant

Associate Members

Name	*Corps, etc.*	*Rank*
Andrewes, H.	Royal Air Force (V.R.)	Flt.-Lieut.
Angier, J. R. T.	Royal Army Ordnance Corps	Lieutenant
Bailey, H. P. V.	Royal Army Ordnance Corps	Major
Ballard, W. E.	Royal Air Force	Pilot Officer
Barratt, G. A.	Royal Navy	Captain
Benner, P. K.	Royal Engineers	Major
Best, H. G.	Royal Artillery	2nd Lieut.
Brewis, J. M.	Royal Army Ordnance Corps	Major
Brown, H. R.	Royal Signals	Lieutenant
Brunner, H. T.	Royal Army Ordnance Corps	Lieutenant
Cameron, D. H.	Royal Engineers	2nd Lieut.
Coates, G. H.	Royal Signals	Lieutenant
Damant, E. L. B.	Royal Navy	Commander
Daniel, F. J.	Royal Army Ordnance Corps	Lieutenant
Davidson, H. S.	Border Regiment	Captain
Davies, F. H.	Royal Air Force	Pilot Officer
Downes, F. A.	Royal Air Force	Pilot Officer
Dungey, A. C.	Royal Naval Volunteer Reserve	Lieutenant
Fahey, G.	Royal Army Ordnance Corps	Lieutenant
Falk, G. F.	Royal Signals	Major
Fendick, A. C.	Royal Army Ordnance Corps	Captain
Finch, K. W.	Royal Naval Volunteer Reserve	Sub-Lieut.
Gartside, A.	Royal Army Ordnance Corps	Lieutenant
Halton, G. H.	Royal Army Ordnance Corps	Captain
Hornby, W. M. P.	Royal Navy	Commander
Hough, F. A.	Royal Signals	Lieutenant
Huff, W. C.	Royal Signals	Captain
Isaac, F. C.	Royal Navy	Sub-Lieut.
Jefferson, J. C.	Royal Army Ordnance Corps	Captain
Johnson, G. W.	Royal Army Ordnance Corps	Lieutenant
Knight, H. E.	Royal Signals	Captain
Lake, R. A.	Royal Engineers	Sapper
Loehnis, C.	Royal Navy	Lieut.-Comdr.
Lucas, F. N.	Royal Signals	Lieutenant
Lye, D. H. C.	Royal Engineers	Staff Captain
McGillewie, D. I.	Royal Navy	Captain
McNaughton, A. G. L.	1st Canadian Division	Major-General
McVicar, J.	Royal Army Ordnance Corps	Major
Maddison, W. H.	Royal Engineers	2nd Lieut.
Mathews, D. C. H.	Royal Engineers	2nd Lieut.
Morgan, A.	Royal Air Force	Squadron Leader
Olson, A. H. F.	Honourable Artillery Company	Gunner
Parkin, G. W.	Royal Army Ordnance Corps	Major
Parr-Dudley, E. A.	Royal Engineers	Major
Pass, C. W.	Royal Army Ordnance Corps	Lieutenant
Phillips, I. G. E.	Royal Army Ordnance Corps	Lieutenant
Pollard, S. M.	Royal Army Ordnance Corps	Lieutenant
Reeves, S. K.	Royal Air Force	Corporal
Sanderson, D. H. S.	Royal Signals	Captain
Scroggie, M. G.	Royal Air Force	Flt.-Lieut.
Somerville, H. B.	Royal Signals	Major
Stead, C.	Royal Signals	Lieutenant
Stokes, E. G. C.	Royal Air Force	Squadron Leader
Terry, J.	Royal Engineers	Cadet
Tugwood, J. R.	Royal Artillery	Gunner
Tye, E.	Royal Engineers	Sapper
Vulliamy, A. T.	Royal Navy	Lieutenant
Waite, D.	Royal Signals	2nd Lieut.
Walker, A. W. P.	Royal Army Ordnance Corps	Lieutenant
Wallace, N. M.	Royal Signals	Lieutenant
Warner, E. J.	Royal Army Ordnance Corps	Lieutenant
Whittaker, H.	Royal Air Force (V.R.)	Hon. Flt.-Lieut.
Wills, F. P.	Royal Signals	Lieutenant

Associates

Cripps, C. F.	Royal Army Ordnance Corps	Captain
Hawkeswood, A. E.	Royal Navy	Petty Officer Telegraphist
MacKellar, C. E.	Royal Artillery	Lieut.-Col.
Reilly, S.	Royal Engineers	Captain
White, H. W.	Royal Engineers	Lieutenant

Graduates

Apps, A. F.	Royal Engineers	Sapper
Ashley, J. E.	Royal Engineers	Staff Sergeant
Austin, G. N.	Royal Artillery	Gunner
Axworthy, F. R.	Royal Engineers	Sapper

* See *Journal I.E.E.*, **85**, p. 653.

Name	Corps, etc.	Rank
Balean, H. H.	Royal Navy	Sub-Lieut.
Beazley, B. S.	Royal Engineers	Cadet
Berge, M.	Royal Signals.	2nd Lieut.
Bird, W. A.	Royal Engineers	Sapper
Bishop, T. R. J.	Royal Engineers	Captain
Brecknell, W. A.	Royal Artillery	Gunner
Brigstocke, W. G. P.	Royal Navy	Lieutenant
Campling, J. N.	Royal Naval Volunteer Reserve	Engineer Sub-Lieut.
Clark, T. F.	Royal Navy	Electrical Artificer.
Clarke, A. C. W. V.	Royal Engineers	2nd Lieut.
Clegg, J. E.	Royal Air Force	Scientific Officer
Conradi, G. H. E.	Royal Artillery	Gunner
Cowley, T. R.	Royal Engineers	Sapper
Crow, D. R.	Royal Signals	Signalman
Davis, T.	Royal Artillery	Gunner
Earl, V. G.	Royal Naval Volunteer Reserve	Sub-Lieut.
FitzPatrick, C. G.	Royal Army Ordnance Corps	Lieutenant
Garvey, W. E.	Royal Engineers	Sapper
Gatley, T. A. B.	Royal Engineers	Sapper
Gill, J. A. W.	Royal Naval Volunteer Reserve	Sub-Lieut.
Gillitt, E. J.	Royal Naval Volunteer Reserve	Sub-Lieut.
Greening, F. C. G.	Royal Signals	Lieutenant
Hare, H. A.	South Staffordshire Regiment	Captain
Harrison-Watson, N. J.	Royal Artillery	Sergeant
Hawker-Smith, R. E.	Royal Air Force	A.C.1
Hayward, R. K.	Royal Signals	2nd Lieut.
Henderson, G.	Royal Naval Volunteer Reserve	Sub-Lieut.
Heydon, V. A.	Royal Corps of Signals	Signalman
Hills, S. J.	Royal Artillery	Sergeant
Holman, J. A.	Royal Naval Volunteer Reserve	Sub-Lieut.
Kay, H. W.	Royal Artillery	Sergeant
Kendall, M. W.	Royal Army Ordnance Corps	Major
Lawson, W.	Royal Scots	Private
Lee-Richards, K. L.	Royal Naval Volunteer Reserve	Sub-Lieut.
Lord, R.	Royal Air Force	A.C.2
Mackenzie, I.	Royal Signals	Major
McKibbin, E. L.	Royal Navy	Electrical Artificer
Martin, C. T.	Royal Naval Volunteer Reserve	Sub-Lieut.
Matthews-Hunter, C.	Royal Army Ordnance Corps	Lieutenant
Morgan, H. D.	Royal Artillery	Lieutenant
Morgan, J. T.	Royal Army Ordnance Corps	Lance-Corporal
Nepean, E. Y.	Royal Signals	Captain
Nixon, C. W.	Royal Naval Volunteer Reserve	Sub-Lieut.
Oliver, W. H.	Royal Signals	Lieutenant
Parker, J. D.	Royal Signals	Lieutenant
Parry, R. C.	Royal Air Force	Sergeant
Parton, J. E.	Royal Naval Volunteer Reserve	Sub-Lieut.
Patterson, A. G.	Royal Naval Volunteer Reserve	Sub-Lieut.
Pearce, H. R.	Royal Army Ordnance Corps	Lieutenant
Pendleton, L.	Royal Signals	2nd Lieut.
Perry, W. H.	Royal Artillery	Lance-Bombardier
Pickup, H.	Royal Naval Volunteer Reserve	Sub-Lieut.
Pittendrigh, L.W.D.	Royal Air Force	Flt.-Lieut.
Preston, D. G.	Royal Artillery	Gunner
Rankin, R. R. C.	Royal Signals	2nd Lieut.
Raymond, I. V.	Royal Engineers	Mechanist Sgt.-Major
Rice, J.	Royal Signals	Signalman
Richardson, G. O.	Royal Engineers	Lieutenant
Robson, L. F.	Royal Signals	Signalman
Rushton, J. H.	Royal Signals	2nd Lieut.
Sankey, R. G.	Royal Signals	2nd Lieut.
Sedgley, H.	Royal Signals	Corporal
Small, W. H.	Royal Artillery	Gunner
Smith, C. C.	Royal Engineers	Sapper
Southby, A. C.	Honourable Artillery Company	Cadet
Strang, J. B.	Royal Army Ordnance Corps	Lieutenant
Weaire, R. F.	Royal Signals	2nd Lieut.
Webb, E. T. A.	Royal Naval Volunteer Reserve	Sub-Lieut.
Webb, W.	Royal Naval Volunteer Reserve	Lieutenant
Webster, E. A.	Royal Signals	Signalman
Wheat, R. H.	Royal Engineers	Corporal
Wilson, H.	Royal Artillery	Bombardier
Winckworth, J. W.	Royal Engineers	2nd Lieut.
Wormall, J. B.	Royal Army Ordnance Corps	Lieutenant
Wright, A. E. A.	Royal Army Ordnance Corps	Lieutenant

Students

Name	Corps, etc.	Rank
Amos, A. P. G.	Royal Air Force	Leading Aircraftman
Beach, J.	Royal Engineers	Lance-Corporal
Benson, H. S.	Royal Artillery	Bombardier
Bicket, J. H.	Royal Army Ordnance Corps	Private
Bishop, J. B.	Officer Cadet Training Unit	Cadet
Book, J. W.	Royal Engineers	Corporal
Brown, F. L.	Royal Engineers	Sapper
Bulford, F. F.	Royal Engineers	2nd Lieut.
Chaplin, J. J.	Royal Engineers	Sapper
Choppen, D. A. E.	Royal Engineers	Sapper
Dixon, G. W.	Royal Artillery	Gunner
Evans, D. D.	Royal Army Ordnance Corps	Staff Sergeant
Evans, P. L.	Royal Signals	Corporal
Fletcher, R. C.	Honourable Artillery Company	Gunner
Franklin, E. B.	Royal Army Ordnance Corps	Private
Goodship, G.	Royal Naval Volunteer Reserve	Sub-Lieut.
Gower, H. J. C.	Royal Army Ordnance Corps	Staff Sergeant
Heywood, C. P. E.	Royal Navy	Sub-Lieut.
Hicks, A. J.	East Surrey Regiment	Private
Housden, G. A. J.	Royal Artillery	2nd Lieut.
Hurford, D. G.	Royal Army Ordnance Corps	2nd Lieut.
Jones, C. W.	Royal Naval Volunteer Reserve	Sub-Lieut.
Karamelli, A. H.	Royal Signals	Signalman
Keeling, J. P. J.	Royal Naval Volunteer Reserve	Sub-Lieut.
Lawson, D. W.	Royal Signals	Signalman
Longman, P. H.	Royal Signals	Signalman
Lynott, T. P.	Royal Engineers	Sapper
Mayers, G.	Royal Army Ordnance Corps	Private
Newman, G. W.	Royal Artillery	Gunner
Nicholson, J.	Royal Engineers	Sapper
Owen, G. R.	Royal Engineers	Sapper
Roberson, R. S.	Royal Signals	Signalman
Robinson, R. E. H.	Royal Signals	Lieutenant
Shaw, M.	Royal Engineers	Sapper

Name	Corps, etc.	Rank
Simpson, K. G.	Royal Army Ordnance Corps	Private
Smither, H.	Royal Signals	2nd Lieut.
Stewart, A. C.	Royal Naval Volunteer Reserve	Able Seaman
Tough, J.	Royal Air Force	A.C.2
Vowles, A. F.	Royal Tank Regiment	Lance-Corporal

LOCAL CENTRE COMMITTEES ABROAD

The present constitution of the Local Centre Committees abroad is as follows:—

Argentine

W. E. Tremain (*Chairman*).
G. W. Munday (*Vice-Chairman*).

E. Berry.
B.G.Borissow, B.Sc.(Eng.).
C. T. T. Comber.
K. N. Eckhard.
A. P. Gunston.
D. H. Nye.

R. G. Parrott (*Hon. Secretary*).

China

J. Haynes Wilson, M.C. (*Chairman*).
W. C. Gomersall (*Vice-Chairman*).

W. A. Ankerson, B.Sc. (Eng.).
S. Flemons.
A. H. Harvey.
F. J. Hookham, B.Sc.
C. H. Mellor.
W. Miles.
A. B. Raworth.
S. Stucken, B.A.
W. H. Wei, B.Sc.(Eng.).

J. A. McKinney (*Hon. Secretary*).

OVERSEAS COMMITTEES

The present constitution of the Overseas Committees is as follows:—

Australia

NEW SOUTH WALES.

P. S. Saunderson (*Chairman*).

V. J. F. Brain, B.E.
L. F. Burgess, M.C.
W. R. Caithness.
E. F. Campbell, B.Eng.
R. V. Hall, B.E.
V. L. Molloy.
A. S. Plowman.

QUEENSLAND.

J. S. Just (*Chairman and Hon. Secretary*).

W. Arundell.
A. Boyd, D.Sc.
E. B. Freeman, B.Eng.
F. R. L'Estrange.
L. G. Pardoe, B.Eng.

SOUTH AUSTRALIA.

F. W. H. Wheadon (*Chairman and Hon. Secretary*).

J. R. Brookman, M.E.
E. V. Clark.
J. S. Fitzmaurice.
Sir W. G. T. Goodman.
W. Inglis.
J. C. Stobie, B.E.

VICTORIA AND TASMANIA.

H. R. Harper (*Chairman and Hon. Secretary*).

J. M. Crawford.
H. C. Newton.
T. P. Strickland.
R. J. Strike.
S. H. Witt.

WESTERN AUSTRALIA.

J. R. W. Gardam (*Chairman*).

F. C. Edmondson.
Prof. P. H. Fraenkel, B.E.
S. Johnson.
W. H. Taylor.

A. E. Lambert, B.E. (*Hon. Secretary*).

Ceylon

Major C. H. Brazel, M.C. (*Chairman*).

H. Fenton-Jones.
C. H. Jones.
D. Lusk.
G. E. Misso.
R. H. Paul, M.A., B.Sc.
E. H. Targett.
G. R. Wiltshire.

D. P. Bennett (*Hon. Secretary*).

India

BOMBAY.

R. G. Higham (*Chairman*).

S. J. W. Baldwin.
C. M. Cock.
K. M. Dordi.
N. R. Khambati.
E. G. Lazarus.
G. L. Rhodes, M.A.

A. L. Guilford, B.Sc.Tech. (*Hon. Secretary*).

CALCUTTA.

F. T. Homan (*Chairman*).

K. N. Arnold.
N. C. Bhattacharji.
C. R. Bland.
E. B. C. Preston.
S. W. Redclift.
Prof. F. W. Sharpley, F.R.S.E.
K. G. Sillar.

D. H. P. Henderson (*Hon. Secretary*).

LAHORE.

V. F. Critchley (*Chairman*).

J. C. Brown.
M. A. Haque.
Prof. T. H. Matthewman.
S. S. Kumar, M.Sc.(Eng.).
P. N. Mukerji, M.Sc.
T. S. Rao, B.E.
N. Thornton.

S. Singh, M.Sc. (*Hon. Secretary*).

MADRAS.

E. J. B. Greenwood (*Chairman*).

K. Aston, M.Sc.
Major E. G. Bowers, M.C.
C. V. K. Chetty, M.B.E., B.A., B.Sc.Tech.
L. Henshaw.
C. K. N. Iyengar, B.E.
A. S. James, M.C.
K. P. P. Menon, B.A., B.Sc.
T. J. Mirchandani, M.Sc. (Eng.).
J. J. Rudra, M.A., Ph.D., B.Sc.
R. M. Steele.
G. Yoganandam, B.E.

W. Le C. de Bruyn (*Hon. Secretary*).

New Zealand

F. T. M. Kissel, B.Sc. (*Chairman*).

R. H. Bartley.
M. C. Henderson.
E. Hitchcock.

J. McDermott (*Hon. Secretary*).

South Africa

TRANSVAAL.

W. Elsdon-Dew (*Chairman and Hon. Secretary*).

J. B. Bullock.
S. E. T. Ewing.
V. Pickles.
B. Price.
Prof. O. R. Randall, Ph.D., M.Sc.
A. Rodwell.
L. B. Woodworth.

COMMITTEES, 1939–40*

Meter and Instrument Section Committee

Chairman: F. E. J. Ockenden.
Vice-Chairman: C. W. Marshall, B.Sc.
Immediate Past-Chairman: Captain B. S. Cohen, O.B.E.

A. H. M. Arnold, D.Eng., Ph.D.
A. T. Dover.
A. Felton, B.Sc.(Eng.)
L. B. S. Golds.
E. Grundy, B.Sc.Tech.
C. W. Hughes, B.Sc.
A. E. Jepson.
F. J. Lane, M.Sc.
E. H. Miller.
E. W. Moss.
A. E. Quenzer.
S. H. Richards.

And

A representative of the Council.
The Chairman of the Papers Committee.

Transmission Section Committee

Chairman: F. W. Purse.
Vice-Chairman: H. J. Allcock, M.Sc.
Immediate Past-Chairman: S. R. Siviour.

C. F. Bolton.
W. M. Booker.
N. K. Bunn.
P. K. Davis.
R. E. G. Horley.
Prof. W. J. John, B.Sc. (Eng.).
S. W. Melsom.
J. S. Pickles, B.Sc.Tech.
T. R. Scott, B.Sc.
F. H. Sharpe.
J. A. Sumner.
H. Willott Taylor.

And

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—
Central Electricity Board: C. W. Marshall, B.Sc.
Electricity Commission: H. W. Grimmitt.
Post Office: P. B. Frost, B.Sc.(Eng.).

Wireless Section Committee

Chairman: E. B. Moullin, M.A., Sc.D.
Vice-Chairman: R. L. Smith-Rose, D.Sc., Ph.D.
Immediate Past-Chairman: A. J. Gill, B.Sc.(Eng.).

R. P. G. Denman, M.A.
T. E. Goldup.
A. J. A. Gracie, B.Sc.
H. L. Kirke.
G. S. C. Lucas.
J. S. McPetrie, D.Sc., Ph.D.
W. L. McPherson, B.Sc. (Eng.)
Col. G. D. Ozanne, M.C.
W. J. Picken.
J. A. Ratcliffe, M.A.
M. G. Scroggie, B.Sc.
R. T. B. Wynn, M.A.

And

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—

Admiralty: Capt. L. V. Morgan, C.B.E., M.V.O., D.S.C., R.N.
Air Ministry: N. F. S. Hecht.
Post Office: A. H. Mumford, B.Sc.(Eng.).
War Office: Col. R. Elsdale, O.B.E., M.C., M.A.

Among the committees appointed by the Council for 1939–40 are the following:—

* The President is, *ex-officio*, a member of all Committees of The Institution.

Home Security Advisory Committee

S. B. Donkin.
P. Good.
H. W. Swann.
H. T. Young.

Benevolent Fund Committee

The President (*Chairman*).

H. S. Ellis	Representing the Council.
F. Gill, O.B.E.	
Prof. R. O. Kapp, B.Sc.	
Sir George Lee, O.B.E., M.C.	
A. P. Young, O.B.E.	
H. T. Young	
J. R. Cowie	Representing the Contributors.
H. Marryat	
C. W. Marshall, B.Sc.	

And the Chairman of each Local Centre in Great Britain and Ireland.

Informal Meetings Committee

M. Whitgift (*Chairman*).

H. Brierley.
G. Davidson.
J. R. Jones.
A. G. Kemsley.
W. A. Ritchie.
F. Jervis Smith.
H. G. Taylor, M.Sc.
F. L. Veale.

And

A representative of the General Purposes Committee.
The Chairman of the Papers Committee.
The Chairman of the London Students' Section.

Model General Conditions Committee

P. V. Hunter, C.B.E.
F. Lydall.
A. E. Tanner.

And

E. G. Batt	British Electrical and Allied Manufacturers' Association
C. Proctor Banham	
V. Watlington, M.B.E.	
The Hon. J. R. Rea	
H. A. F. Bennett	Cable Makers' Association.
H. C. C. Budd	
J. A. Lee	Central Electricity Board.
J. C. Dalton	Incorporated Association of Electric Power Companies.
R. Birt	Incorporated Municipal Electrical Association.
A. Nichols Moore	
P. L. Rivière	London Electricity Supply Association.
G. W. Spencer Hawes, O.B.E.	Provincial Electric Supply Association.

Operating Theatres Electrical Apparatus Committee

Forbes Jackson.
E. H. Rayner, M.A., Sc.D.
H. W. Swann.
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng.
Prof. D. T. A. Townend, D.Sc., Ph.D.
H. T. Young.

And	*Representing*
Lionel Colledge, F.R.C.S.	British Medical Association.
R. W. L. Phillips	I.E.E. Wiring Regulations Committee.
P. G. Phelps	Manufacturers of electro-medical apparatus.
E. H. Willis	
H. S. Souttar, C.B.E.	Royal College of Surgeons.
Dr. C. F. Hadfield, M.B.E., M.A.	Royal Society of Medicine.

Local Centres Committee

J. R. Beard, M.Sc.
W. Fennell.
P. Good.
A. L. Lunn.
Col. Sir Thomas F. Purves, O.B.E.
C. S. Taylor.
H. T. Young.

And the Chairman of each Local Centre and Sub-Centre.

Overseas Activities Committee

Sir Noel Ashbridge, B.Sc. (Eng.).
Lieut.-Col. K. Edgcumbe, T.D.
A. P. M. Fleming, C.B.E., D.Eng., M.Sc.
F. Gill, O.B.E.
W. G. Hendrey.
C. S. Taylor.

And

The Chairman of the Finance Committee.
The Chairman of the General Purposes Committee.
The Chairman of the Membership Committee.
The Chairman of the Papers Committee.

Also the following co-opted members:—

J. W. Bell.
Prof. J. K. Catterson-Smith, M.Eng.
W. P. Gauvain.
A. C. Kelly.
F. Lydall.
J. T. Mertens.
E. A. Mills.
H. Nimmo.
E. E. Sharp.
A. L. Stanton.
V. Watlington, M.B.E.

Scholarships Committee

Prof. J. K. Catterson-Smith, M.Eng.
J. M. Donaldson, M.C.
Prof. Willis Jackson, D.Sc., D.Phil.
Prof. W. J. John, B.Sc.(Eng.).
Prof. E. W. Marchant, D.Sc.
H. Marryat.

"Science Abstracts" Committee

L. G. Brazier, Ph.D., B.Sc.
P. Good.
Prof. E. W. Marchant, D.Sc.
C. C. Paterson, O.B.E., D.Sc.

And	*Representing*
J. H. Awbery, B.A., B.Sc. ..	Physical Society.
Prof. A. Ferguson, M.A., D.Sc.	Physical Society.
D. Owen, B.A., D.Sc. ..	Physical Society.
W. Jevons, D.Sc., Ph.D. ..	Physical Society.
R. H. Fowler, O.B.E., M.A. ..	Royal Society.

Ship Electrical Equipment Committee

A. G. S. Barnard.
Major B. Binyon, O.B.E., M.A.
J. H. Collie.
Dr. P. Dunsheath, O.B.E., M.A.
S. Harcombe, M.A., B.Sc.
A. Henderson.
J. F. W. Hooper.
P. V. Hunter, C.B.E.
F. Johnston.
J. W. Kempster.
A. Cecil Livesey.
S. W. Melsom.
N. W. Prangnell.
Col. A. P. Pyne.
C. Rodgers, O.B.E., B.Sc., B.Eng.
F. A. Ross.
T. A. Sedgwick.
H. D. Wight.
H. A. Wilson.

And	*Representing*
J. S. Pringle, O.B.E.	Admiralty.
H. Cranwell ..	Board of Trade.
W. T. Williams, O.B.E.	Board of Trade.
B. Hodgson ..	British Corporation Register of Shipping and Aircraft.
J. Turnbull ..	British Corporation Register of Shipping and Aircraft.
T. Ratcliffe, M.Sc.Tech. ..	British Electrical and Allied Manufacturers' Association.
C. W. Saunders ..	British Electrical and Allied Manufacturers' Association.
E. W. Andrews ..	Electrical Contractors' Association.

And	*Representing*
S. A. Smith, M.Sc.	Institute of Marine Engineers.
N. H. Swancoat ..	Institute of Marine Engineers.
J. F. Nielson ..	Institution of Engineers and Shipbuilders in Scotland.
W. J. Belsey ..	Institution of Naval Architects.
S. F. Dorey, D.Sc.	Lloyd's Register of Shipping.
G. O. Watson ..	Lloyd's Register of Shipping.
W. S. Wilson ..	North-East Coast Institution of Engineers and Shipbuilders.
(To be nominated)	Electrical Contractors' Association of Scotland.

Wiring Regulations (Nucleus) Committee

H. J. Cash.
P. Dunsheath, O.B.E., M.A., D.Sc.
W. Fennell.
E. B. Hunter.
P. V. Hunter, C.B.E.
H. Marryat.
R. W. L. Phillips.
F. W. Purse.
E. Ridley, M.B.E.
C. Rodgers, O.B.E., B.Sc., B.Eng.
J. F. Stanley, B.Sc.(Eng.).

REPRESENTATIVES OF THE INSTITUTION ON OTHER BODIES

The following is a list of representatives of The Institution on other bodies, and gives the dates on which they were appointed:—

Admiralty:

Selection Committee for Vacancies for Assistant Electrical Engineers:

R. T. Smith (1 July, 1937).

Bristol University:

H. F. Proctor (8 Jan., 1925).

British Cast Iron Research Association:

E. B. Wedmore, C.B.E. (25 Sept., 1924).

British Electrical and Allied Industries Research Association:

Council:

J. M. Donaldson, M.C. (18 Dec., 1930).
P. V. Hunter, C.B.E. (16 Nov., 1939).

Sub-Committee on Connections to Large Gas-filled Lamps:

C. C. Paterson, O.B.E., D.Sc. (24 Oct., 1929).
B. Welbourn (24 Oct., 1929).

Sub-Committee on Earthing and Earth Plates:

S. W. Melsom (31 Jan., 1930).

British Electrical Development Association: Committee on Rural and Agricultural Electrification:

J. M. Donaldson, M.C. (20 Oct., 1927).
R. Grierson (20 Oct., 1927).

British Standards Institution:

Engineering Divisional Council:

Sir George Lee, O.B.E., M.C. (22 April, 1937).
C. C. Paterson, O.B.E., D.Sc. (10 March, 1938).
Col. Sir Thomas F. Purves, O.B.E. (27 April, 1939).

Electrical Industry Committee:

Lt.-Col. K. Edgcumbe, T.D. (5 March, 1925).
F. Gill, O.B.E. (21 May, 1914).
J. S. Highfield (21 May, 1914).
E. H. Shaughnessy, O.B.E. (23 March, 1933).
R. T. Smith (21 May, 1914).

Technical Committee on Electric Power Cables:

E. B. Hunter (31 Dec., 1936).
Col. A. P. Pyne (3 Nov., 1938).
G. O. Watson (31 Dec., 1936).
H. D. Wight (31 Dec., 1936).

Technical Committee on Electric Clocks:

E. B. Hunter (5 Dec., 1935).

Technical Committee on Electric Signs:

L. Barlow (14 May, 1931).
R. W. L. Phillips (17 Feb., 1932).

Technical Committee on Electrical Accessories:

H. J. Cash (31 March, 1925).
F. W. Purse (31 March, 1925).

Technical Committee on Electrical Instruments:

Lt.-Col. K. Edgcumbe, T.D. (15 Feb., 1923).

Technical Committee on Electrical Nomenclature and Symbols:

C. C. Paterson, O.B.E., D.Sc. (8 Jan., 1920).

Technical Committee on Electricity Meters:

A. J. Gibbons, B.Sc.Tech. (28 March, 1930).
O. Howarth (22 Oct., 1936).
G. F. Shotter (28 Feb., 1929).

Technical Committee on Identification of Pipe-lines in Buildings:

R. Grierson (11 May, 1933).

Technical Committee on Lifts, Hoists, and Escalators:

H. Marryat (25 Oct., 1934).

Technical Committee on Overhead Transmission Lines Material:

J. L. Eve (11 Nov., 1936).

Technical Committee on Provision in Buildings for Ducts for Service Pipes:

H. J. Cash (1 Dec., 1938).
E. B. Hunter (1 Dec., 1938).

British Standards Institution—*continued.*

Technical Committee on Regulations for Overhead Lines:

W. Fennell (23 April, 1936).
S. R. Siviour (23 April, 1936).

Technical Committee on Safety Requirements:

H. J. Cash (22 Oct., 1936).
R. W. L. Phillips (22 Oct., 1936).
E. Ridley, M.B.E. (11 Feb., 1937).

Technical Committee on Testing and Expressing the Overall Performance of Radio Receivers:

R. P. G. Denman, M.A. (21 Oct., 1937).

Technical Committee on Under-floor Duct Systems:

E. B. Hunter (22 Oct., 1936).
H. W. Swann (22 Oct., 1936).

Technical Committee on Wireless Apparatus and Components:

E. H. Shaughnessy, O.B.E. (30 Sept., 1925).

Sub-Committee on Automatic Change-over Switches for Emergency Lighting Systems:

E. Ridley, M.B.E. (22 Oct., 1936).

Sub-Committee on Cables for Use on Board Ship:

A. Henderson (18 May, 1939).
E. B. Hunter (20 Oct., 1938).
Col. A. P. Pyne (3 Nov., 1938).
G. O. Watson (20 Oct., 1938).
H. D. Wight (20 Oct., 1938).

Sub-Committee on Ceiling Roses:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Conduit Fittings:

H. J. Cash (18 May, 1927).

Sub-Committee on Connectors for Portable Appliances:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 May, 1937.)

Sub-Committee on Connectors for Radio Apparatus:

R. W. L. Phillips (6 Jan., 1931).

Sub-Committee on Copper Conduit Tubes (Light Gauge):

H. Marryat (17 Dec., 1936).

Sub-Committee on Cut-outs for Radio Receivers:

S. W. Melsom (5 Dec., 1935).

Sub-Committee on Distribution Boards:

E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Fuses:

H. J. Cash (22 June, 1926).
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).
G. O. Watson (23 Feb., 1939).

British Standards Institution—*continued.*

Sub-Committee on Instrument Transformers:
G. F. Shotter (22 Feb., 1934).

Sub-Committee on Lead Alloys for Cable Sheathing:
B. Welbourn (22 June, 1933).

Sub-Committee on Letter Symbols:
A. T. Dover (21 Nov., 1929).

Sub-Committee on Low-voltage Transformers for Lighting Equipment and Bell-ringing Circuits:
G. F. A. Norman (11 Feb., 1937).

Sub-Committee on Mains Supply Apparatus for Radio Receivers, etc.:
R. W. L. Phillips (11 Dec., 1930).
F. W. Purse (16 Oct., 1928).

Sub-Committee on Non-ignitable and Self-extinguishing Boards for Electrical Purposes:
S. W. Melsom (24 Oct., 1935).
E. Ridley, M.B.E. (24 Oct., 1935).

Sub-Committee on Porcelain Insulators for Overhead Lines:
P. K. Davis (11 May, 1939).
H. Willott Taylor (11 May, 1939).

Sub-Committee on Protected-type Plugs and Sockets:
H. J. Cash (26 Oct., 1932).
F. W. Purse (26 Oct., 1932).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Radio Interference from Trolleybuses and Tramcars:
C. C. Paterson, O.B.E., D.Sc. (7 Nov., 1935).
H. Wallis (7 Nov., 1935).

Sub-Committee on Radio Nomenclature and Symbols:
Col. A. S. Angwin, D.S.O., M.C., B.Sc.(Eng.) (7 April, 1932).

Sub-Committee on Telephone and Radio Connectors:
R. W. L. Phillips (28 Feb., 1935).
A. J. L. Whittenham (28 Feb., 1935).

Sub-Committee on Tumbler Switches:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Wall-plugs and Sockets:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Welding Plant and Equipment:
Major J. Caldwell, J.P. (26 Oct., 1933).

Panel on Graphical Symbols for Interior Installations:
G. F. A. Norman (11 Feb., 1937).
E. Ridley, M.B.E. (11 Feb., 1937).

Colliery Requisites Industry Committee:
C. T. Allan (3 July, 1924).

Technical Committee on Mining Electrical Plant:
A. C. Sparks (27 March, 1930).

British Standards Institution—*continued.*

Birmingham Regional Committee:
F. C. Hall.

Glasgow Regional Committee:
F. Anslow.

Manchester Regional Committee:
W. T. Anderson.

Newcastle Regional Committee:
S. A. Simon, B.A.

Sheffield Regional Committee:
M. Wadeson.

Technical Committee for Co-ordinating the Work on Units and Quantities of the Building, Chemical, and Engineering Divisional Councils:
E. B. Wedmore, C.B.E. (3 Feb., 1938).

Technical Committee for the Standardization of Clamps for connecting Earthing Wires to Metal Water Pipes:
F. W. Purse (16 Nov., 1939).

Technical Committee on Coal:
W. M. Selvey (19 Jan., 1928).

Technical Committee on Engine Testing Fittings:
W. M. Selvey (22 Oct., 1931).

Technical Committee on Engineering Symbols and Abbreviations:
A. T. Dover (21 Nov., 1929).

Technical Committee on Fans:
Prof. R. O. Kapp, B.Sc. (22 Oct., 1931).

Technical Committee on Land Boilers:
W. M. Selvey (7 April, 1932).

Technical Committee on Larch Poles:
B. Welbourn (21 Jan., 1932).

Technical Committee on Lightning Conductors:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (30 Jan., 1936).

Technical Committee on Measurement of Temperature, Flow, and Pressure of Fuel and Flue Gases:
G. A. Whipple, M.A. (28 April, 1938).

Technical Committee on Methods of Test for Dust Extraction Plant:
C. L. Blackburn, B.A. (25 Oct., 1934).

Technical Committee on Pipe Flanges:
W. M. Selvey (14 April, 1921).

Technical Committee on Pump Tests:
R. S. Allen (2 July, 1931).

Technical Committee on Railway Signalling Apparatus:
A. F. Bound (24 Oct., 1929).

Technical Committee on Rating of Rivers:
G. K. Paton (20 Oct., 1927).

British Standards Institution—*continued.*

Technical Committee on Rubber Belting:

C. Rodgers, O.B.E., B.Sc., B.Eng. (5 Jan., 1928).

Technical Committee on Standardization of Letter Symbols:

L. G. Brazier, Ph.D., B.Sc. (4 July, 1939).

Technical Committee on Traction Poles:

T. L. Horn (4 Feb., 1926).

Sub-Committee on Accessories for Land Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Boiler and Superheater Tubes:

W. M. Selvey (7 April, 1932).

Sub-Committee on Fittings for Land Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Water-Tube Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Portable Railway Track:

R. T. Smith (25 Oct., 1928).

Illumination Industry Committee:

Lt.-Col. K. Edgcumbe, T.D. (28 Feb., 1924).
P. Good (28 Feb., 1924).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (28 Feb., 1924).
J. W. J. Townley (16 May, 1935).

Welding Industry Committee:

T. Carter (2 Feb., 1939).

Building Industry, National Council for:

Advisory Committee on Building Acts and Bye-Laws:

F. W. Purse (20 Oct., 1932).
H. T. Young (20 Oct., 1932).

Magnesite Composition Flooring Panel:

F. W. Purse (21 Oct., 1937).

Lifts and Escalators Installation Panel:

L. S. Atkinson (30 Mar., 1939).

Central Register of National Service:

General Engineering Committee:

J. R. Beard, M.Sc. (23 Feb., 1939).
W. K. Brasher, B.A. (13 Oct., 1939).
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (15 Dec., 1938).
H. T. Young (23 Feb., 1939).

City and Guilds of London Institute:

Advisory Committee on Electrical Engineering Practice:

Prof. E. W. Marchant, D.Sc. (22 June, 1933).

Advisory Committee on Electrical Installation Work:

Prof. S. Parker Smith, D.Sc. (20 Oct., 1927).

Advisory Committee on Illuminating Engineering Examinations:

C. C. Paterson, O.B.E., D.Sc. (8 April, 1937).

City and Guilds of London Institute—*continued.*

Advisory Committee on Machine Design:

F. H. Clough, C.B.E. (2 Feb., 1939).

Advisory Committee on Telecommunications:

E. H. Shaughnessy, O.B.E. (22 Oct., 1931).

Fellowship Committee:

W. H. Eccles, D.Sc., F.R.S. (19 April, 1928).

Council for the Preservation of Rural England:

J. M. Kennedy, O.B.E. (10 Jan., 1929).

Electrical Association for Women:

Council:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (18 Dec., 1924).

Committee for Training of Women Demonstrators.

J. R. Beard, M.Sc. (4 Nov., 1937).

Engineering Joint Council:

The President (*ex-officio*).
J. M. Kennedy, O.B.E. (20 Feb., 1936).
H. T. Young (24 Feb., 1938).

Engineering Joint Examination Board:

Prof. C. L. Fortescue, O.B.E., M.A. (24 Mar., 1938).
Prof. R. O. Kapp, B.Sc. (3 Nov., 1938).

Engineering Public Relations Committee:

J. M. Kennedy, O.B.E. (6 May, 1937).

Registration of Engineers Sub-Committee:

J. M. Kennedy, O.B.E. (20 Oct., 1938).

Sub-Committee for Scotland:

Major H. Bell, O.B.E., T.D. (23 May, 1938).

H.T. Conference, Paris: British National Committee:

F. H. Clough, C.B.E. (10 Mar., 1938).
A. H. Railing, D.Eng. (10 Mar., 1938).

Imperial College of Science and Technology: Governing Body:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (20 Oct., 1938).

Imperial Minerals Resources Bureau Conference: Copper Committee:

B. Welbourn (18 Sept., 1919).

Institute of Industrial Administration: Examinations Advisory Council:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Oct., 1934).

Institute of Metals: Corrosion Research Committee:

W. M. Selvey (19 July, 1923).

Institution of Civil Engineers:

Engine and Boiler Testing Committee:

C. P. Sparks, C.B.E. (19 Oct., 1922).

Earthing to Water Mains Sub-Committee:

P. Dunsheath, O.B.E., M.A., D.Sc. (20 Feb., 1936).
F. W. Purse (20 Feb., 1936).
P. J. Ridd (20 Feb., 1936).

Institution of Civil Engineers—*continued.*

Engineering Precautions (Air Raid) Committee Panel:

S. B. Donkin (11 May, 1939).

International Association for Testing Materials:

J. M. Kennedy, O.B.E. (5 July, 1928).

International Illumination Commission: British National Committee:

Lt.-Col. K. Edgcumbe, T.D. (27 Nov., 1913).
P. Good (18 Sept., 1919).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (27 Nov., 1913).
J. W. J. Townley (16 May, 1935).

Joint Committee for National Certificates and Diplomas in Electrical Engineering (England and Wales):

E. S. Byng (16 Nov., 1939).
Prof. C. L. Fortescue, O.B.E., M.A. (4 Nov., 1937).
E. B. Moullin, M.A., Sc.D. (16 Nov., 1939).

Joint Committee for National Certificates and Diplomas in Electrical Engineering (Scotland):

Prof. G. W. O. Howe, D.Sc. (10 Jan., 1929).
D. S. Munro (8 Nov., 1934).
R. Robertson, D.L., B.Sc., LL.D. (10 Jan., 1929).
Prof. S. Parker Smith, D.Sc. (10 Jan., 1929).

Joint Committee of the British Electrical and Allied Industries Research Association and The Institution of Civil Engineers, for Research on Earthing to Water Mains:

C. W. Marshall, B.Sc. (24 Feb., 1938).
F. W. Purse (3 Feb., 1938).
W. G. Radley, Ph.D.(Eng.) (3 Feb., 1938).

Joint Committee on Engineering Co-operation Overseas:

F. Gill, O.B.E. (28 April, 1938).

Joint Committee on Materials and their Testing:

S. W. Melsom (16 July, 1938).

Joint Fuel Committee:

C. P. Sparks, C.B.E. (7 Jan., 1932).

Manchester Regional Advisory Council for Technical and other Forms of Further Education: Post Advanced Education Sub-Committee:

L. H. A. Carr, M.Sc.Tech. (20 Jan., 1938).
Prof. Willis Jackson, D.Sc., D.Phil. (11 May, 1939).
J. W. Thomas, LL.B., B.Sc.Tech. (20 Jan., 1938).

Metalliferous Mining (Cornwall) School: Governing Body:

L. A. Hards (1 Dec., 1927).

National Physical Laboratory: General Board:

J. M. Donaldson, M.C. (7 Nov., 1935).
P. Dunsheath, O.B.E., M.A., D.Sc. (3 Nov., 1938).

National Register of Electrical Installation Contractors:

H. J. Cash (12 March, 1931).
P. V. Hunter, C.B.E. (18 Feb., 1926).
W. R. Rawlings (18 Feb., 1926).
W. M. Selvey (18 Feb., 1926).

National Smoke Abatement Society:

H. C. Lamb (26 Oct., 1933).
C. D. Taite (26 Oct., 1933).

Professional Classes Aid Council:

W. K. Brasher, B.A. (7 Dec., 1939).

Royal Engineer Board:

W. B. Woodhouse (19 March, 1925).

Royal Institute of British Architects: Advisory Committee to Re-draft Home Office Handbook No. 5 on Structural Precautions:

H. T. Young (5 Oct., 1939).

Royal Society:

National Committee on Physics:

Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (19 Nov., 1936).

National Committee for Scientific Radio:

Prof. C. L. Fortescue, O.B.E., M.A. (19 Nov., 1936).
Sir George Lee, O.B.E., M.C. (5 Oct., 1939).

Science Museum, South Kensington: Advisory Council:

C. C. Paterson, O.B.E., D.Sc. (1 July, 1937).

Town Planning Institute: Committee on Overhead Transmission Lines:

J. M. Kennedy, O.B.E. (7 April, 1932).

Union of Lancashire and Cheshire Institutes (Panel for Engineering):

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (28 Feb., 1924).
Prof. Miles Walker, M.A., D.Sc., F.R.S. (28 Feb., 1924).

University College, Nottingham: Electrical Engineering Advisory Committee:

A. D. Phillips (23 Feb., 1933).

War Office Mechanization Board:

W. H. Eccles, D.Sc., F.R.S. (19 Jan., 1928).

Women's Engineering Society:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Sept., 1924).

World Power Conference (British National Committee):

Sir Archibald Page (28 April, 1938).

ELECTIONS AND TRANSFERS

At the Ordinary Meeting of The Institution on the 16th November, 1939, the following elections and transfers were effected:—

Elections

Members

Boetje, Herman Jacobus.
Cameron, James Somerville, B.Sc.

Associate Members

Aldis, Ronald Edward.
Ashton, Walter.
Benner, Paul Ker, Major, R.E.
Birch, Arthur Leonard.
Blunt, Peter, B.Sc.
Bower, Arthur Cecil.
Broughton, John Haward
Brown, Hugh.
Buckingham, Frederick, B.Sc.
Charles, Frank Nichols.

Associate Members—continued.

Cook, George Herbert.
Douglas, Robert Stoddart, B.Sc.
Dunham, Carlton Rosslyn, M.A.
Gilson, Eric Friend, B.Sc.
Gottlieb, Salomon Shlomo.
Harris, Edward Valentine.
Hitchen, Herbert.
Holdsworth, Maurice.
Humby, Albert Maurice.
Hunter, William.
Hurlston, Frank Arnold.
Kilgour, Alexander.
Kulkarni, Purushottam Parshuram.
Leckie, Walter Francis.
Lockyer, Edward Norman.
London, Herbert John.
McConnell, Thomas.
Melio, Louis George, B.Sc.
Mercer, Thomas.
Mukerji, Ganesh Chandra, B.Sc.
Nash, David John, B.Sc. (Eng.).
Polson, Reginald Alexander, B.E.
Pope, Ernest Edward.
Ross, Douglas Graham.
Simon, Robin Howard S., M.A.
Simpson, Geoffrey Arrol G.
Stokes, Edgar George C.
Style, Humphrey Bloomfield, B.A.
Swettenham, George Arthur V.
Tobin, Edward.
Topham, Arthur Henry.
Vincze, Stephen Alexander.
Ward, Harold Ridlington H.
Webster, Rupert Kenley.

Companion

Atherton, Thomas.

Associates

Bancroft, Walter.
Foden-Petchler, Robert, Capt., M.C.
Foster, William.
Paterson, Robert Sinclair.
Perry, Thomas Charles.
Pemberton, Hereward Leslie.
Smith, Ernest.
White, Harold.
Williams, Philip Idwal.

Graduates

Agnew, Alexander Gilmour, B.Sc.
Anderson, John Graham P., B.Sc.(Eng.).
Ashcroft, James Martland.
Askew, Joseph Hordon.
Aston, Leonard George.
Austin, William Harry.
Bagnall, John Stuart, B.Sc. Tech.
Bailey, Ronald, B.Sc.
Bartlett, Frederick William George.
Batcock, Bernard John.
Baumann, Francis Edgar, B.A.
Belsey, Frederick Harold.
Birrell, Robert Cuthbertson.
Bond, George Dennis.
Bridcut, John Kenneth, B.Sc.(Eng.).
Cornish, Reginald Edward.
Cowley, Thomas Richard.
Critch, Arthur Clifford.
Croney, Joseph, B.Sc. (Eng.).
Dawson, James Reginald.
Dolphin, George Thomas Wheeler, B.Sc.(Eng.).
Eales, Edward Reginald.
Edwards, James Alfred, B.Sc.
Fisher, William Hawarden, B.Sc.
Francis, Roy Sevior.
Gates, Richard Ellison.
Goody, Leslie John.
Gourgey, Reginald Elias.
Green, William Henry F.
Hales, Ronald Leslie.
Harford, Peter Harry, B.Sc.
Inglis, William Laurence.
Inman, Victor Henry T.
Jones, Jack, B.Sc.(Eng.).
Jones, Patrick Ludlow F.
Lockton, William Henry.
Lu, Yin-Hsieh, B.Sc.
McGuire, Patrick Bowen.
McKinnon, John Cyril R., B.Sc.Tech.
Mercer, Wilfred J.
Monk, Charles Edward.

Graduates—continued.

Montgomery, Ronald David, B.Sc.
Mooraj, Nazerhusein Fazil.
Morss, Alexander William.
Palfrey, Harold Charles.
Pao, Hsi-Nien, B.Sc.(Eng.).
Patterson, Andrew Graham.
Pendse, Sharatkumar Gajanan, B.A.
Porter, George Herbert.
Pratt, Thomas.
Prickett, Victor Charles R.
Reilly, Frederick John, B.Sc.
Renshaw, George Albert.
Richards, John, B.Sc.
Rochester, Robert.
Scaddan, Alfred James.
Scott, Peter John M., B.Sc. (Eng.).
Seaden, Ernest Robert, B.Sc.(Eng.).
Shinnie, Robert Vaucour M.
Sihota, Gurbakhsh Singh, B.Eng.
Silcock, Samuel.
Slater, Ian George.
Slater, René George.
Smith, Edmund, B.Sc. (Eng.).
Steuer, Henryk.
Strang, John Braithwaite.
Stritch, George Seymour, B.A.
Sumner, John.
Tarsey, Stanley George.
Taylor, Evan Drummond, B.Sc.
Thomas, Leonard Ellis, B.Sc.
Umpleby, Kenneth Frederick, B.A.
Walker, Frederick.
Walton, Gordon Herbert Francis, B.Sc.(Eng.).
Widdis, Frederick Charles, B.Sc.(Eng.).
Wilson, Thomas Colston, B.Sc.Tech.
Wolfe, Maurice O'Brien W.

Students

Ackermann, Eric George.
Aldridge, Leslie James.
Anderson, Ronald.
Andrews, Donald William.
Armitage, Thomas.
Arnold, Peter Arthur.
Arrol, Ian.
Baker, Sidney.
Begley, Marcus Dill.
Benito, Craig Silverdore.
Benson, Harold Sydney.
Berwin, Charles Arthur.
Bowie, George Alexander.
Brooks, Leslie James.
Brown, Frederick Leslie.
Brown, William.
Buckler, Raymond Robert.
Burniston, Ronald Leslie.
Calverley, Thomas Earnshaw.
Carpenter, Victor Stanford.
Chaston, Robert Henry.
Choppen, Douglas Albert Edwin.
Choudhri, Ghulam Ahmad.
Clark, Arthur Jack R.
Cohen, George Samuel.
Conway, William Ronald.
Cosgrave, Stanford Thomas.
Cranham, Sidney George.
Crawford, Arthur Beaumont M.
Cullis, Arthur David S.
Denner, James Railton.
Donnelly, Henry Ernest A.
Dunbar, George MacDonald.
du Parcq, John Renouf, B.A.
Dutt, Ajoy Kumar.
Duxbury, Arnold.
Dyer, Peter Kenneth A.
Fletcher, Douglas.
Ford, William Perrins.
Forster, Albert Edward T.
Forsyth, Eric Francis, B.Sc.
Gee, Peter Arthur.
Geere, Nigel Ernest.
Gibbins, Francis William.
Gibbins, Wilfrid David.
Gilbert, Martin Thomas.
Gleeson, John.
Grant, Fraser.
Gregson, William Derek H.
Gutteridge, James Limbird.
Haddon, John.
Hall, Percy George.
Hall, William.
Hargreaves, Howard Roy.
Harrington, Basil George V.
Hartley, Eric James.
Hatton, Edward Derek.
Haynes, Joseph.
Hearle, William Lawry.

Students—continued.

Henley, William Ronald.
Holland, John.
Holliday, Sydney.
Holloway, Stanley James.
Hoon, Ong Kim.
Howard, Fernley Jack.
Ince, John Francis R.
Ison, Douglas Stuart.
James, John Gordon.
Jenkin, Peter.
Johnson, Bernard Kenneth.
Jones, Patrick Clive.
Jones, Raymond Dennis.
Kelsey, Edric Fryatt.
Kenner, Henry David.
Kenney, Antony Joseph.
King, Maurice James, B.A.
Kirtley, Peter Allan.
Knowles, Royston.
Kok, Giedeon Jakobus.
Laidlaw, Denis William.
Lawrence, Edmund John.
Lewis, Thomas Henry.
Lilburn, Alistair James.
Mackay, Alexander Charles.
Maguire, Denis Richard.
Markland, Alfred King.
Mayers, Geoffrey.
Meggs, Robert Stanley.
Mercer, George Geoffrey.
Miller, Kenneth Mackay.
Milne, Frank Alexander.
Mittra, Provat Chandra.
Mordey, Alan Ainslie F.
Mountjoy, Basil James.
Murdoch, Samuel Scott.
Narayanaswamy, G.
O'Connor, John William.
Odlum, Anthony Henry R.
O'Hare, Michael Daniel.
O'Leary, George Austin.
Ong, Tan Theam.
Parker, Ralph Lawrence.
Pask, Douglas Alexander.
Pendlebury, Cedric Howard.
Pickering, Geoffrey Wharne.
Pridmore, John.
Radington-Meech, John Richard.
Reed, Gerald Gordon.
Reed, John Howard.
Reynolds, Bertram Thomas.
Ridgers, John Percival.
Robertson, James Cameron.
Robertson, William Banks.
Rolfe, Edward.
Rushton, Frank.
Shaw, Derek Charles.
Shore, Alec.
Shorland, Harry.
Short, Ralph Eric.
Singh, Kirpal Sagoo.
Smith, John.
Smith, Leonard Harris.
Stephenson, Herbert Francis.
Sugars, Eric Gordon.
Symonds, William Percival.
Thomas, David Ernest.
Thomson, Francis Paul.
Thoy, Wong Koon.
Tillson, Philip Eric.
Tod, John Norman.
Topping, John.
Trenhail, Arthur.
Tricker, Geoffrey Richard.
Tucknott, Robert George.
Venkataraman, Mayavaram Krishnaswami R.
Walker, John Irwin.
Walton, Alfred Leslie G.
Watkins, Basil Hubert.
Watson, Wilfred.
Wells, Alfred William E.
Westbrook, Hugh Wyeth.
Wilson, Geoffrey.
Wilson, Godfrey Charles I.
Wingrove, Douglas Harry.
Wood, George Herbert.
Wood, Walter.
Woodcock, Harry.
Wyllie, Horace.
Yeo, Mervyn James.
Yorke, James Martin.
Young, James.

Transfers

Associate Member to Member

Ahern, Patrick Joseph.
Ailleret, Pierre Marie J.
Aitken, Ian Miller, B.Sc. (Eng.).
Evans, Evan John, M.Sc. (Eng.).
Henderson, John, M.C., B.Sc.
Higgins, Clifford, B.Sc. (Eng.).
MacEwan, Harry Camden.
Mallinson, George Gill.
Miles, Percy Vincent C. R.
Preston, Charles Ernest, M.Eng.
Puritz, Mario E.
Sethna, Rustam Maneckjee.
Sproull, Alexander Wallace, Lieut.-Colonel, B.Sc.
Wyborn, Edward John, B.Sc.(Eng.).

Associate to Associate Member

Baskerville, James Joseph P.
Frankland, Charles Hayes.
Hill, David Smith.
Holt, Robert Dickinson.
Lord, Bernard Stevenson.
McLean, George Clark.
Tubb, Burton Henry J.
Warman, Arthur Charles.
Warren, William.

Graduate to Associate Member

Aubrey, Richard.
Bailey, Hugh Philip V.
Baker, Claude Frederick G.
Barker, Robert Henry.
Bass, Edward Endersby.
Baxendale, Clifford Cooper.
Bayley, Ronald Hugh P.
Bentley, Roland David, M.A.
Berkeley, Julius John C.
Berry, Hugh William, Flying Officer.
Bowerbank, Geoffrey, B.Sc.
Brash, Eric Bayliss, B.Sc.
Bunyan, Thomas Walter, B.Sc.(Eng.).
Burgess, Ronald Alexander.
Cameron, Donald Henry, B.Sc.(Eng.).
Campbell, Ian Colin, B.Sc. (Eng.).
Campbell, James.
Caplin, Frank, B.Sc.(Eng.).
Chapman, Arthur Horsley, B.E.
Child, Arthur Harry.
Chynoweth, Frederick.
Collins, John Edward.
Connelly, Denis, B.Sc.
Cropper, Edward Samuel, G., B.Sc.(Eng.).
Datta, Promod Behari.
Davey, Claude, B.Sc.
Dodman, Edward John.
Dungey, Alan Cecil, B.Sc. (Eng.).
Edgell, James Francis.
Fahey, George, B.Sc.
Fair, John William.
Flynn, George Henry R., Lieut., R.Signals, M.B.E.
Gale, Henry Major, B.Sc.
Gardner, Charles Everson, B.Sc.
Gilks, Francis Richard.
Gilling, Reginald Sidney, B.Sc.(Eng.).
Graham, Kenneth Alexander.
Guscott, William James.
Handyside, John Stewart.
Hanlon, Frederick Alexander.
Harding, Alan Douglas.
Harris, Bernard John, B.E.
Harris, Wilbur Edward C., B.Sc.
Hawken, Joseph John.
Helliwell, Kenneth.
Hill, Charles James W.
Hill, Norman Ernest G., B.Sc.(Eng.).
Hind, Douglas McGechan, B.Sc.
Hind, Harry.
Hindle, Robert Arnold.
Ibbotson, Donald Briggs.
Irens, Alfred Norman.
Jayasekara, Don Paulis, B.Sc.(Eng.).
Jeffs, Harold.
Johnson, Alec Owen, B.Sc. Tech.
Junnarkar, Nilkanth Ramchandra.
Kerr, Albert Edward.
King, Alfred Frederick.
Langston, Frederick William H.
Lauderdale, Fred Stockdale.
Lenton, Herbert Savery.
Lett, Frederick Tom.
Lovelock, Ralph Tweed.
Lowe, Sidney Roland.
Macdonald, Stewart James B.Sc.
MacLeod, Albert James C.
Malkani, Tolaram Khemchand, B.Sc.Tech.
Martin, Thomas George.
Meadows, Frederick Percival, B.Sc.
Meek, John (Junr.), B.Sc. (Eng.).
Mehta, Kalidas Himatlal.

Graduate to Associate Member—continued.

Miller, William Leslie E.
Montgomery, Stuart Haldane.
Morcom, William John, B.Sc.(Eng.).
Morgan, Edward, B.Sc.
Muir, John Stilwell.
Ogden, John Ashton, B.Sc. Tech.
Oura, Hector Leslie, B.Sc. (Eng.).
Page, Arthur Ronald.
Page, Harold, B.Sc.
Parker, George Percy.
Parr, Asa.
Pendlington, Laurence.
Perkins, Henry Whitworth.
Phillips, Ambrose Robert C., B.Sc.
Pryor, Charles Geoffrey, B.Sc.
Pulvermacher, Francis Howard.
Ramchandani, Atmaram Chartsing, B.Sc.Tech.
Reardon, John.
Reynolds, George Alan.
Rhodes, Bernard, B.Sc.
Robinson, Alfred.
Roden, Frank Albert, B.Sc. (Eng.).
Rogers, Joseph William, B.E.
Ross, John.
Sanders, Kenneth Lesreaulx.
Scott, Sydney Wallace.
Shorter, Donovan Ernest L., B.Sc.(Eng.).
Smith, Eustace Herbert, B.Sc.(Eng.).
Spencer, Frederick Elliot V.
Sprague, William Steains, B.Sc.
Stead, Clifford, B.Sc.
Stevenson, Ian Douglas, M.Sc.
Stowell, Peter d'Eyncourt, B.Sc.(Eng.).
Thomas, Jack, B.Sc.
Thomson, William, B.Sc.
Thursfield, Donart, M.A.
Truscott, David Netherclift, Ph.D., B.Sc.(Eng.).
Tubb, Frederick Richard.
Underwood, Ronald Herbert.
Vargassoff, Nicolas, B.Sc.
Vivian, George Edward, B.Sc.(Eng.).
Wagstaff, William Percy, B.Sc.
Wakefield, Kevin Stuart.
Walker, Geoffrey Eades.
Waterton, Frank William.
Weare, Henry Owen.
Wickenden, Robert Henry, B.Sc.(Eng.).
Williams, Richard George.
Wilson, Henry Sherwood.
Winstanley, Edward, B.Sc. (Eng.).
Worth, Thomas Bertram.
Yates, George Arthur.

Student to Associate Member

Jones, Frank.
Warren, Geoffrey Cyril D.
Woolfson, Mark.

The following transfers were also effected by the Council at their meeting held on the 26th October, 1939:—

Student to Graduate

Abbott, Rolfe Merton F.
Alexander, John Finlay.
Anstey, Frank Bernard B.Sc.(Eng.).
Atkinson, Frederick Booth, B.Eng.
Axworthy, Francis Roy.
Babb, Alexander Hammond.
Balasundaram, Narayanaswamy.
Barber, Alan.
Barette, Kenneth.
Barker, Stuart.
Barnard, Ernest Walter.
Bartlett, James George.
Basford, Aubrey Newton.
Bayford, Leslie John.
Bawtree, Harold Maurice.
Beaumont, Ernest.
Bennett, William Gordon, B.Eng.
Bentley, Donovan Vernon C.
Betterton, Ernest Charles.
Biddle, Gordon Cropthorne.

Student to Graduate—continued.

Birch, Frederic Henry, B.Sc.(Eng.).
Blagden, Richard, B.Sc.
Blake, Peter Maurice.
Boulton, Brian.
Bowers, Robert.
Bradshaw, Harold.
Brewitt-Taylor, Edward Gordon, B.Sc.
Broad, John Harold S.
Brodrick, Alfred Gerald.
Brookes, Maurice Meridyth.
Brooks, Norman Colston, B.Sc.(Eng.).
Bull, Eric William, M.Sc. (Eng.).
Busby, Albert William.
Buxton, Alan Jeffery, B.Sc. (Eng.).
Buzza, Herbert.
Bygate, Richard Anthony.
Byram, Harold.
Bywater, Kenneth Athorne V.
Campbell, Alex Matthewson.
Canfor, Ronald James.
Capes, John Philip.
Carroll, John Walter, B.Sc. (Eng,).
Caswell, Arthur Frederick.
Chambers, George Stanley M.
Clark, Reginald.
Clark, Thomas Foster.
Clifford, Henry Phillimore, B.Sc.
Cocker, Henry Lawrence.
Coles, Douglas Harry.
Common, Raymond Percy.
Cooper, Ronald, B.Sc.
Coutts, John Edward.
Cow, John Charles, B.Sc.
Cox, Ernest Francis.
Cranage, William Walter.
da Costa, Francis Edward.
Darwin, John Francis B., B.Eng.
Davies, Miss May Thora, B.Sc.(Eng.).
Davies, Thomas George.
Dimbleby, Leslie Charles.
Dobell, Leslie Thomas F.
Dolman, Frank Kenneth.
Dunsford, Kenneth Martin.
Durnford, John, B.Sc. (Eng.).
Durston, David Stanley.
Dyson, Leonard.
Earl, John Wakelin.
Eggleton, Charles William.
Emery, William John G.
Evans, John Vincent, B.Sc.
Fair, James Benjamin.
Fawcett, Dennis, B.Sc. (Eng.).
Field, George.
Finn-Kelcey, Peter Gerard.
Fitton, Edward Douglas, B.Sc.(Eng.).
Fitzpatrick, James.
Foicik, Reginald John.
Forster, Peter Charles T., B.Sc.(Eng.).
Foster, Fred William.
Frazer, Thomas Athol.
Fuller, Frank Martin.
Galloway, James John.
Gaylard, Richard Percival.
George, John Maxim B.
Goddard, Norman Sidney.
Gordon, Evelyn Raymond F.
Grant, Maurice Ivor.
Gray, John Alwyn.
Green, Raphael Samuel, B.Sc.(Eng.).
Gregory, Kenneth George.
Griffith, Robert Mervyn, B.E.
Grubb, Kenneth Oliver.
Hague, George Edward P.
Hampton, Denis Allen.
Hare, John.
Harris, John.
Harrison, David Wallis.
Hart, Alexander Roy.
Hartgroves, Frederick Leslie G.
Hartley, Frank, B.Eng.
Hawkins, Philip Owen.
Heath, Frederick Walter.
Henbest, Reginald George.
Henderson, John Stuart, B.Sc.
Herbert, Raymond Mawson.
Hickling, Charles Geoffrey.
Hobbs, Edwin Daniel.
Holloway, Kenneth George.
Horner, Eric.
Howard, John Purvis.
Huckell, Noel Raymond, B.Sc.
Jamieson, Ian Alastair, B.Sc.(Eng.).
Jennings, Robert Edward.
Jones, Peter Bailey.
Jones, Leslie Gordon.
Jones, Leslie Llewellyn.
Jones, Maurice Clement.
King, Charles John, B.Sc. (Eng.).

Student to Graduate—continued.

King, Harold Reginald.
Kitchen, Frank Harvey, B.Eng.
Knowles, John.
Knowlson, William John.
Lee, Chih-Wu, B.Sc.
Le Souef, Francis Albert W., B.Eng.
Levin, Arthur.
Lieberman, Lionel, B.Sc. (Eng.).
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Beattie, Malcolm Hamilton.
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Donnan, William Kelly, B.Sc.
Francis, Stanley James.
Hawkins, John Mitchell.
Hoyle, John.
Huntriss, Harold Claude.
McNair, John Ferguson.
Marshall, Raymond Victor.
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Ramanathan, G.
Reed, John Arthur.
Rowland, David, B.Sc. (Eng.).
Shaw, Geoffrey Louis.
Watson, Patrick William L.

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[NOTE.—The books cannot be purchased at The Institution: the names of the publishers and the prices are given only for the convenience of members; (*) denotes that the book is also in the Lending Library.

SMYTHE, W. R. Static and dynamic electricity. 8vo. xviii + 560 pp. (New York; London: McGraw-Hill Publishing Co., Ltd., 1939.) 40*s*. (*)

SPIESER, R. Faults and failures in electrical plant. Causes and results: cure and prevention. By R. S. in collaboration [*with various authors*]. Translated by E. Hunking. With a foreword by D. B. Hoseason. 8vo. xvii + 408 pp. (London: Sir Isaac Pitman and Sons, Ltd., 1939.) 30*s*. (*)

SPON, E. & F. N., LTD. Spon's electrical pocket-book. A reference book of general electrical information, formulae and tables for practical engineers. 7th ed. by W. H. Molesworth and G. W. Stubbings. sm. 8vo. viii + 400 pp. (London: E. & F. N. Spon, Ltd., 1939.) 6*s*.

STERLING, G. E. The radio manual. 3rd ed. vi + 1120 pp. (New York: D. Van Nostrand Co., Inc.; London: Chapman and Hall, Ltd., 1938.) 25*s*. (*)

STRAIMER, G., *Dr.-Ing.* Der Kondensator in der Fernmeldetechnik. 8vo. x + 229 pp. (Leipzig: S. Hirzel, 1939.) *RM*.15.

STRIGEL, R., *Dr.-Ing.* Elektrische Stossfestigkeit. 8vo. x + 317 pp. (Berlin: Julius Springer, 1939.) *RM*.28.50.

STUBBINGS, G. W. The diseases of electrical machinery. A textbook for the use of electricians, apprentices and power plant engineers. sm. 8vo. vii + 219 pp. (London: E. and F. N. Spon, Ltd., 1939.) 7*s*. 6*d*. (*)

—— Electrical testing for practical engineers. A handbook of reference for engineers engaged in the erection and maintenance of electrical installations, plant and machinery. sm. 8vo. vii + 252 pp. (London: E. and F. N. Spon, Ltd., 1939.) 8*s*. 6d. (*)

—— Elementary vectors for electrical engineers. sm. 8vo. viii + 110 pp. (London: Sir Isaac Pitman and Sons, Ltd., 1939.) 5*s*. (*)

TAYLOR, F. H. Private house electric lighting. 15th ed. sm. 8vo. 128 pp. (London: Percival Marshall and Co., Ltd., 1939.) 1*s*. 6*d*. (*)

THOMAS, H. A., *D.Sc.* Theory and design of valve oscillators for radio and other frequencies. With a foreword by E. V. Appleton. 8vo. xviii + 270 pp. (London: Chapman and Hall, Ltd., 1939.) 18*s*. (*)

Thompson, A. J., *Ph.D.* Logarithmetica Britannica. Being a standard table of logarithms to twenty decimal places. Pt. 1, 3–9. (Cambridge: University Press, 1924–37.) 15*s. each part.*

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Timbie, W. H. Industrial electricity: direct-current practice. 2nd ed. 8vo. xii + 635 pp. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1939.) 15*s.* (*)

—— and Higbie, H. H. Essentials of alternating currents. 2nd ed. sm. 8vo. x + 377 pp. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1939.) 11*s.* (*)

Veinott, C. G. Fractional horsepower electric motors. 8vo. xix + 431 pp. (New York; London: McGraw-Hill Publishing Co., Ltd., 1939.) 21*s.* (*)

Waddicor, H. The principles of electric power transmission by alternating currents. 4th ed. 8vo. xxi + 458 pp. (London: Chapman and Hall, Ltd., 1939.) 21*s.* (*)

Wall, T. F., *D.Sc.*, *D.Eng.* Electricity. sm. 8vo. 256 pp. (London: Thornton Butterworth, Ltd., 1939.) 2*s.* 6*d.*

Warren, A. G., *M.Sc.* Mathematics applied to engineering. With a foreword by A. Russell. 8vo. xv + 384 pp. (London: Chapman and Hall, Ltd., 1939.) 15*s.* (*)

Whitehead, E. S. A short account of the life and work of John Joseph Fahie. With a foreword by E. W. Marchant. sm. 4to. ix + 112 pp. (London: Hodder and Stoughton, Ltd., 1939.) 7*s.* 6*d.* (*)

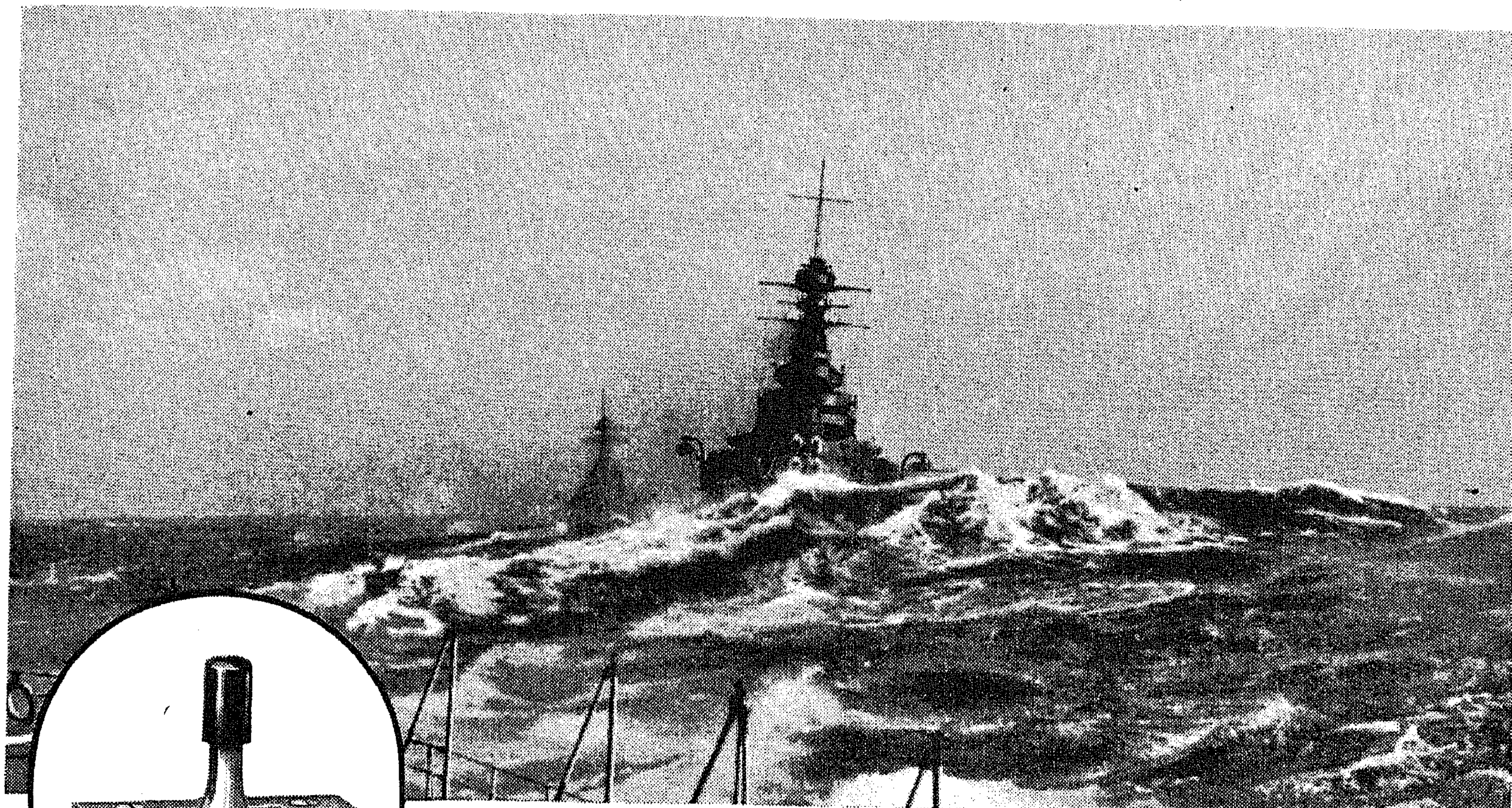
Wilson, A. H. Semi-conductors and metals: an introduction to the electron theory of metals. 8vo. viii + 120 pp. (Cambridge: University Press, 1939.) 7*s.* 6*d.* (*)

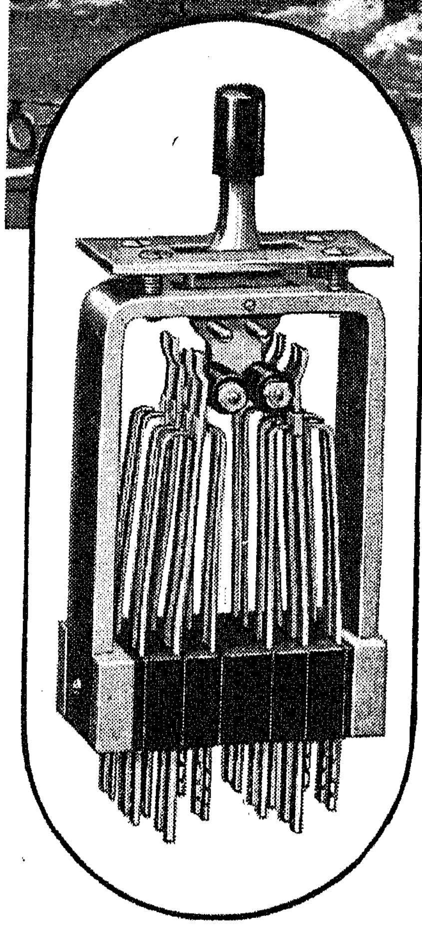
World Power Conference. Statistical year-book of the W.P.C. no. 3, Data on resources and annual statistics for 1935 and 1936. Edited with an introduction and explanatory text by F. Brown. 4to. 138 pp. (London: World Power Conference, 36 Kingsway, W.C.2, 1938.) 20*s.*

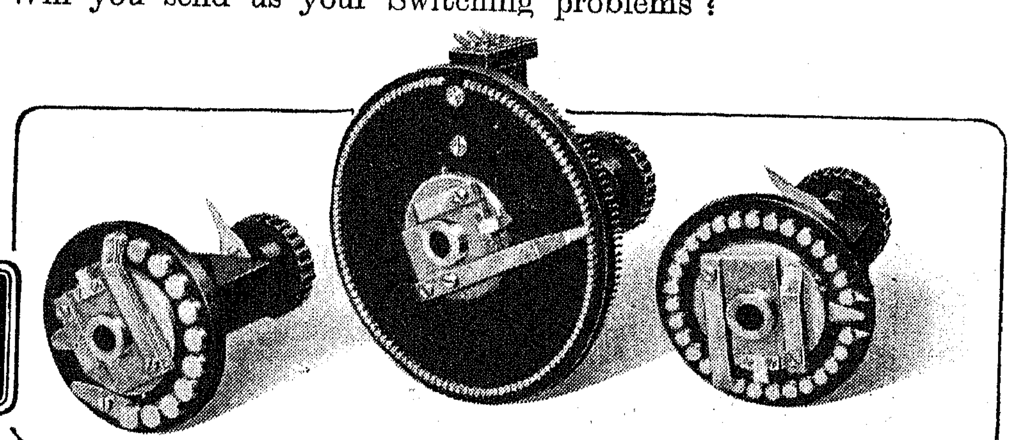
—— Third World Power Conference. Transactions 10 vol. 8vo. (Washington, D.C.: Superintendent of Documents; London: Percy Lund, Humphries and Co., Ltd., 1938.) *Set* £5 18*s.*; *Single volume* 13*s.* 6*d.*

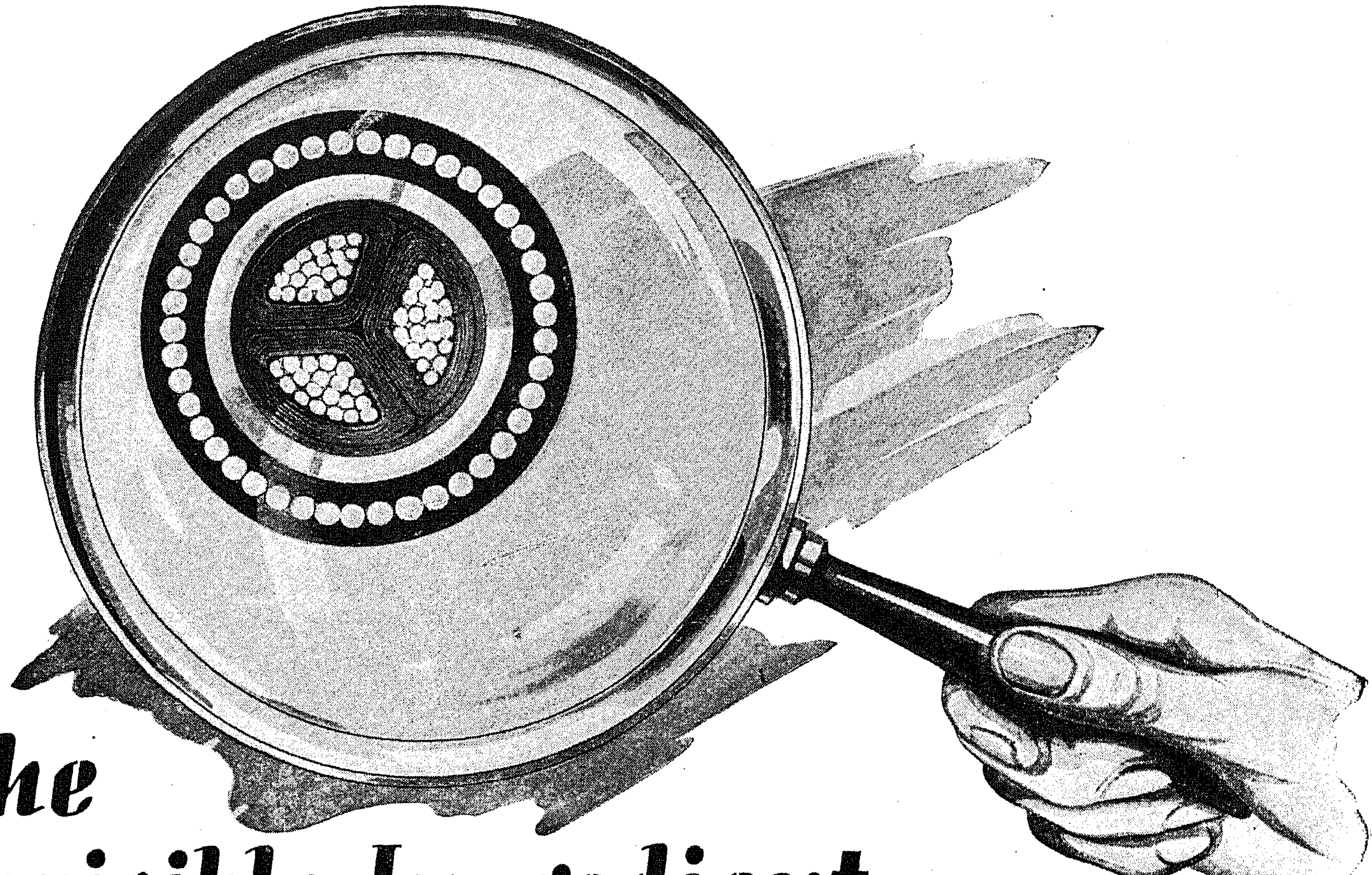
World Radio Convention. Complete proceedings of the W.R.C. held at Sydney, N.S.W., April 4th–14th, 1938. Under the auspices of the Institution of Radio Engineers (Aust.) during Australia's 150th anniversary celebrations. 4to. *pagin. var.* (Sydney: Institution of Radio Engineers (Australia), Box 3120 G.P.O., 1938.) 23*s. post free.*

Young, A. P., *O.B.E.* Plan and serve. With a foreword by Sir F. Pole. sm. 8vo. 140 pp. (London: Management Publications Trust, 3*s.* 6d. 1938.) (*)









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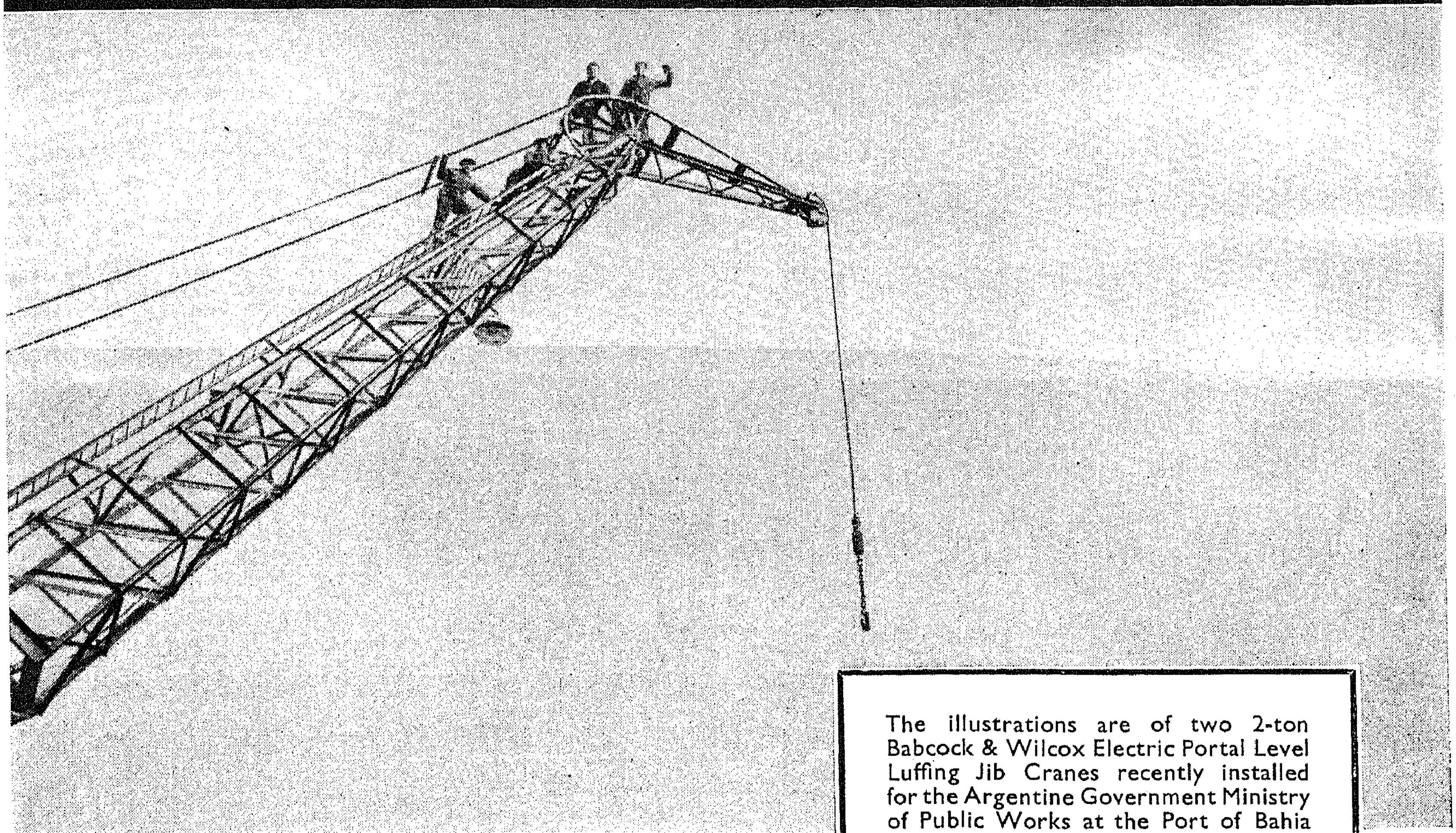

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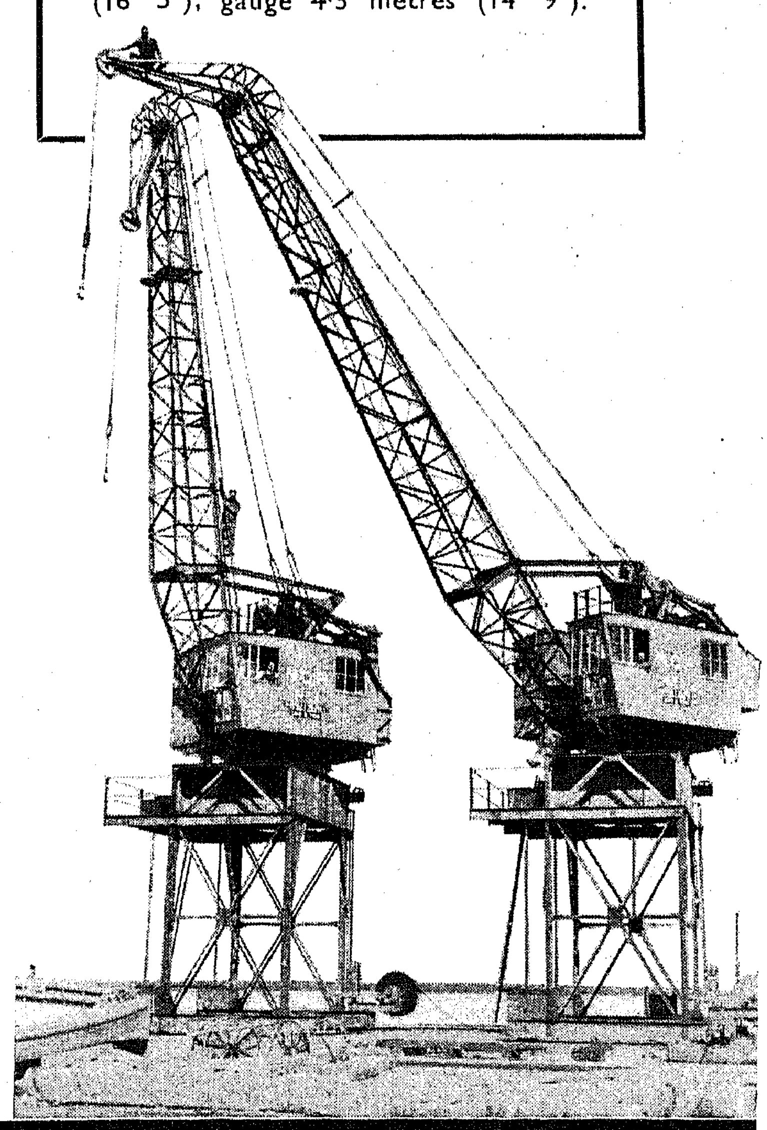

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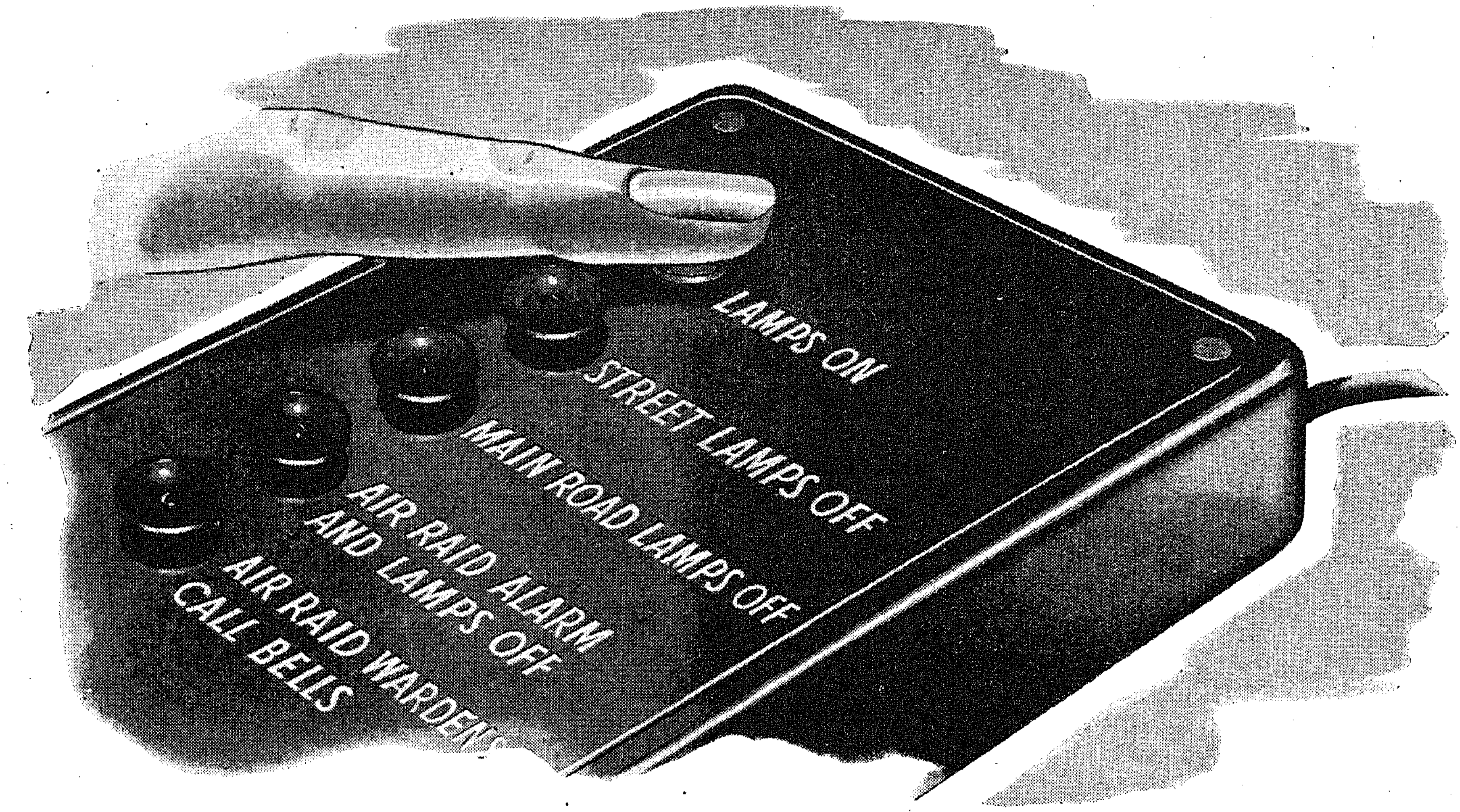

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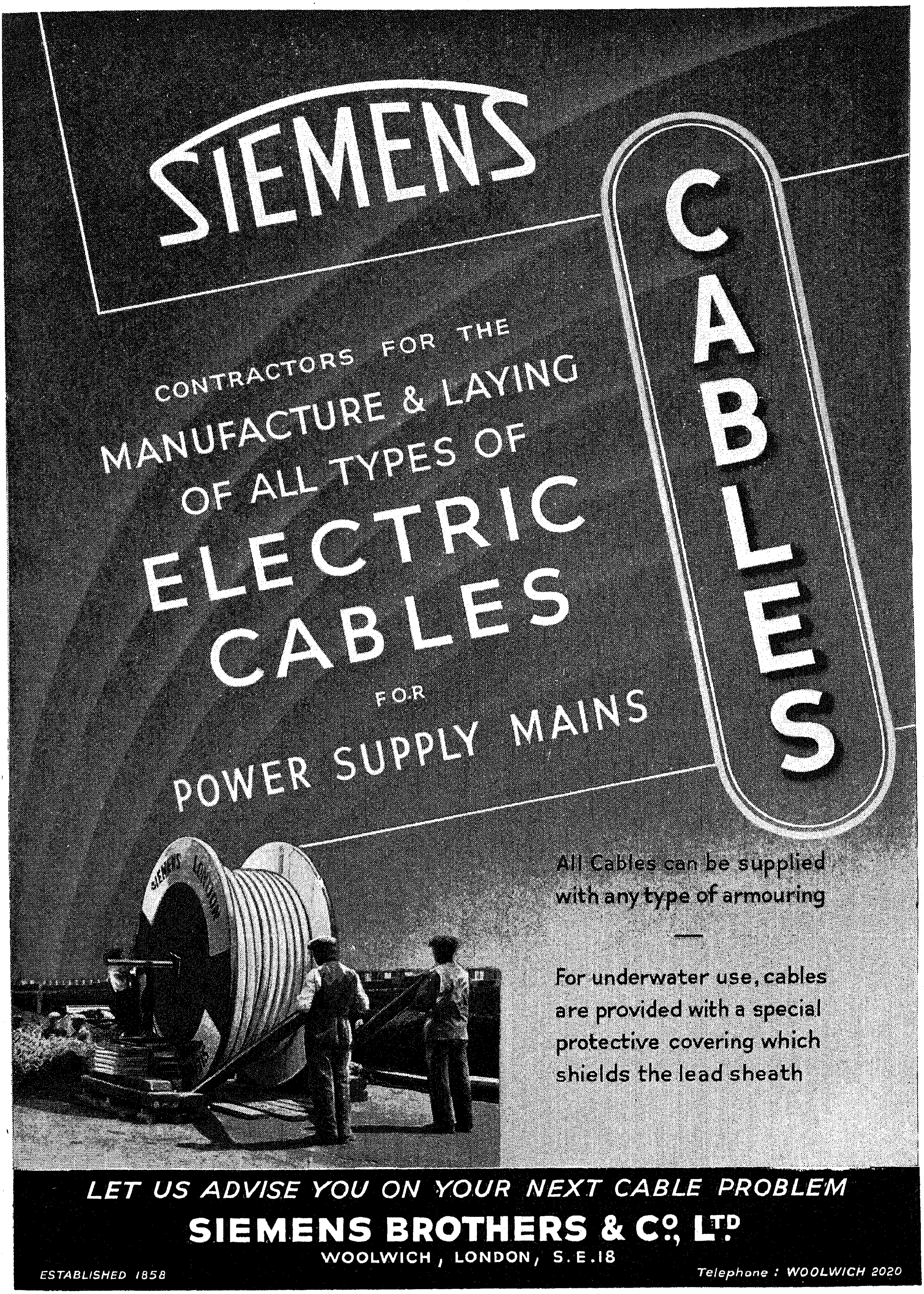
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